

# ASSESSMENT OF SURFACE WATER MODEL MAINTENANCE AND SUPPORT STATUS

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## NOTICE/DISCLAIMER STATEMENT

This report was prepared by Tetra Tech, Inc. under Contract #EP-C-14-016, Work Assignment 3-24, for the United States Environmental Protection Agency (U.S. EPA) Water Modeling Workgroup. The U.S. EPA made comments and suggestions on the report, however the U.S. EPA did not contribute otherwise to the production of the report.

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## INTRODUCTION

The United States Environmental Protection Agency's (EPA) Water Modeling Workgroup (WMW) provides support for core surface water quality modeling tools used in Clean Water Act programs. The WMW identified a set of 18 separate surface water modeling applications that are currently applied to support development of Total Maximum Daily Load (TMDL) plans, assess permit conditions for National Pollutant Discharge Elimination System (NPDES) facilities, evaluate policy and water quality effects of potential actions, and conduct other water quality analyses. The WMW directed Tetra Tech to perform an assessment of the current maintenance and support status of each modeling tool to facilitate the identification of gaps in support or other activities that might warrant future WMW activity.

This report summarizes the findings of Tetra Tech's review of the maintenance and support status of the following modeling applications.

AGNPS	Aquatox	BASINS
BATHTUB	CE-QUAL-ICM	CE-QUAL-W2
CORMIX	EFDC	HAWQS
HSPF	LSPC	QUAL2KW
SPARROW	SWAT	SWMM
SWTOOLBOX	VISUAL PLUMES	WASP

## AGNPS/ANNAGNPS

Agricultural Nonpoint Source Pollution Model (AGNPS) is a modeling tool for use in evaluating the effect of predominantly agricultural management decisions impacting water, sediment and chemical loadings within a watershed system. The model predicts (1) water; (2) sediment by particle size class & source of erosion; and (3) chemicals-nitrogen, phosphorus, organic carbon, & pesticides. The pollutant loadings are generated from land areas and routed through stream systems on a daily basis. Special land use components such as feedlots, gullies, field ponds, and point sources are included.

## MODEL DEVELOPER/STEWARD

AGNPS was developed by the United States Department of Agriculture (USDA) Agricultural Research Service (ARS). USDA continues to provide support for the model.

Ron Bingner is the ARS project manager responsible for the distribution of AGNPS. Ron Binger can be contacted at [Ron.Binger@ars.usda.gov](mailto:Ron.Binger@ars.usda.gov) or (662)232-2966.

## MODEL STATUS

The model name "AGNPS" has been replaced with Annualized AGNPS (AnnAGNPS) and refers to a system of model components which can be used to estimate annualized loads and load reductions. The single event version known as AGNPS was discontinued in the mid-1990's. Several versions that integrate the model with geographic information system (GIS) and Windows-based graphical user interfaces are available.

The most recent version of AnnAGNPS (version 5.45) is dated December 2016. AnnAGNPS versions 5.0 and later incorporate enhanced features for many input and output options including ephemeral gullies, automated calibration for pollutants, actual or potential evapotranspiration climate files, and the ability to enter unlimited climate stations with any naming convention.

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## MODEL CODE

AnnAGNPS is a batch-process, continuous-simulation, surface-runoff, pollutant loading computer model written in standard ANSI FORTRAN 2015.

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## SOURCE CODE

The model (current version 5.45) is a non-proprietary, public domain model with an open source code that can be accessed and downloaded by any individual at the following web site:

<https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=stelprdb1043591>

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## ACCESSIBILITY

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### USER COMMUNITY PORTAL

There is no user community portal.

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## DOCUMENTATION AND TRAINING MATERIALS

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### MODEL THEORY DOCUMENTATION

[AnnAGNPS Technical Processes V5.4 March, 2015](#)

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## USER MANUAL

The AnnAGNPS User's Guide for Input Files & Formats Version v5.45 (August 2016) is included in the model installation package

(<https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=steiprdb1043591>)

- 
- Chemical routines – in situ
  - Chemical reach routing
  - Erosion routine – RUSLE2
  - Error checking
  - Event output files
  - Feedlots
  - Field ponds
  - Ephemeral gullies
  - Hydrograph development
  - Impoundments
  - Internal data preparation
  - Irrigation
  - Overall system
  - Read input
  - Sediment reach routing
  - Composite of soil layers
  - Soil moisture, CN runoff
  - Source accounting
  - Water reach routing
  - Winter routines

The [Input Data Preparation](#) page provides contact information and descriptions of where users can obtain

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## EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

Karki, R., Tagart, M.L., Paz, J.O., Bingner, R.L. (2017). Application of AnnAGNPS to model an agricultural watershed in East-Central Mississippi for the evaluation of an on-farm water storage (OFWS) system. *Agricultural Water Management*. 192:103-114.

Li, H., Cruse, R. M., Bingner, R. L., Gesch, K. R., & Zhang, X. (2016). Evaluating ephemeral gully erosion impact on Zea mays L. yield and economics using AnnAGNPS. *Soil and Tillage Research* (155): 157- 165.

Momm, H.G., Bingner, R.L., Yuan, Y., Kostel, J., Monchak, J.J., Locke, M.A., and Giley, A. (2016). Characterization and placement of wetlands for integrated conservation practice planning. *Trans. of the ASABE*, 59(5): 1345-1357.

Que, Z., Seidou, O., Droste, R.L., Wilkes, G., Sunohara, M., Topp, E., Lapen, D.R. (2015). Using AnnAGNPS to predict the effects of tile drainage control on nutrient and sediment loads for a river basin. *J. Environmental Quality* 44:629-641.

Zema, D.A., Denisi, P., Taguas Ruiz, E.V., Gomez, J.A., Bombino, G., & Fortugno, D. (2016). Evaluation of surface runoff prediction by AnnAGNPS model in a large Mediterranean watershed covered by olive groves. *Land Degradation & Development*, 27: 811-822. DOI: 10.1002/ldr.2390

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#### TRAINING MATERIALS

None.

## AQUATOX

AQUATOX is an ecological simulation model that predicts the impacts of various environmental pollutants on aquatic ecosystems and aquatic organisms including fish, invertebrates and aquatic plants. The aquatic ecosystems that can be modeled include streams, rivers, lakes, reservoirs and estuaries. Hydrodynamics are not simulated within AQUATOX and must be supplied as model inputs. AQUATOX predicts the response of these aquatic ecosystems to multiple stressors including nutrients, organic loadings, sediments, organic chemicals and temperature. AQUATOX is known as a process-based or mechanistic model because it simulates the transfer of biomass, energy and chemicals from one compartment of the ecosystem to another by simultaneously computing each of the most important chemical or biological processes. AQUATOX can be run as a point model, a stratified model (for lakes), and as a two- or three-dimensional model with linked segments depending on the modeling goal.

## MODEL DEVELOPER/STEWARD

Lead developer(s) and affiliation:

Richard Park of Eco Modeling and Jonathan Clough of Warren Pinnacle Consulting Inc. developed AQUATOX for U.S. Environmental Protection Agency (EPA) Office of Water.

Maintenance Status:

AQUATOX is maintained by EPA Center for Exposure Assessment Modeling (CEAM).

## VERSION INFORMATION

AQUATOX was developed in 2002 and has undergone major updates since the initial release, as summarized in Table 1. The model was developed and compiled in Delphi. AQUATOX release 3 is integrated into the BASINS modeling system with a MapWindow interface.

Table 1. Version History

Version	Release Date	Non- Proprietary	Available for Download
Release 1	2002	Yes	No
Release 2	2003	Yes	No
Release 2.1	2005	Yes	No
Release 2.2	2006	Yes	No
Release 3	2009	Yes	No
Release 3.1	2012	Yes	No
Release 3.1 Plus	05/2014	Yes	Yes

For system requirements of the AQUATOX model, see Table 2.

Table 2. System Requirements

	Minimum Requirement	Preferred Requirement
Hardware		Pentium PC, 2.0GHZ or higher (or equivalent)
Operating System	MS Windows 98, 2000, NT, or XP	Windows XP, Vista, 7, or 8
Memory Requirements	1 GB RAM	4 GB RAM
Disk Space	1 GB free disk space	32 GB free disk space



## ACCESSIBILITY

Only Release 3.1 Plus version of AQUATOX is available for download from EPA: [AQUATOX 3.1 Plus Download Page](#). Release 3 is included in the BASINS 4.1 package Release 3.2 is expected in September 2018.

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## SOURCE CODE

The source code is available for download through the About Screen under Help.

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## MODEL LANGUAGE

The source code language is Delphi, and the AQUATOX model must be compiled with Delphi 2007 Professional.

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## User community portals

EPA hosts a listserv for the user community: [AQUATOX listserv](#) . Users can post a messages to the user community or request a search of past messages based on key words.

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## DOCUMENTATION AND TRAINING MATERIALS

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### User Manuals

A user manual and four technical documents comprise the theoretical and computational documentation for AQUATOX.

- [AQUATOX User's Manual Release 3.1 \(2014\)](#)
- [AQUATOX User's Manual Release 2 \(2004\)](#)
- [AQUATOX Technical Document Release 3.1 \(2014\)](#)
- [AQUATOX Technical Note 1: Calibrated Parameter Set for Simulation of Algae in Shallow Rivers \(2009\)](#)
- [AQUATOX Technical Note 2: Requirements, Sources, Conditioning of Data \(2014\)](#)
- [AQUATOX Technical Note 3: Modeling Water Flows \(2014\)](#)

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### Additional Documentation

Additional documentation including guidance on setup and application and parameter sensitivity.

- [Guidance in AQUATOX Setup and Application \(2014\)](#)
- [AQUATOX Sensitivity Analysis \(2014\)](#)

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### Training Materials

EPA has hosted training opportunities and the course material is available on the EPA's [AQUATOX Training Workshops](#) webpage. Training materials include an option for a one-day short course or three-day course. The one-day course materials discuss the capabilities of AQUATOX and provide examples of application. The three-day course materials provide more extensive details of the model and a hands-on example.

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### Recent Application/Reports

[AQUATOX coupled foodweb model for ecosystem risk assessment of Polybrominated diphenyl ethers \(PBDEs\) in lake ecosystems \(2014\)](#)

[Assessment of improvement scenario for water quality in Mogan Lake by using the AQUATOX Model \(2015\)](#)

Establishing nearshore marine injuries for the Deepwater Horizon natural resource damage assessment using AQUATOX (2017)

Food web modeling of a river ecosystem for risk assessment of down-the-drain chemicals: A case study with AQUATOX (2015)

Simulation of a water ecosystem in a landscape lake in Tianjin with AQUATOX: Sensitivity, calibration, validation and ecosystem prognosis (2016)

## BASINS

BASINS is a GIS-based Decision Support System that serves as an interface to several models, including HSPF, SWAT and AQUATOX, that was designed to facilitate the completion of watershed and water quality studies by local, state and regional entities. It uses a geographic information system to bring together key data sets that are utilized by many different modeling applications. It provides for easy access to national environmental data in the application of a number of proven water quality models and assessment tools.

## MODEL DEVELOPER/STEWARD

### Lead developer(s) and affiliation:

The original BASINS (Better Assessment Science Integration Point and Nonpoint Sources) was developed by the U.S. Environmental Protection Agency (US EPA) Office of Water. Technical direction and guidance was provided from US EPA and system development was provided by AQUA TERRA with cooperation from Tetra Tech, Inc., Texas A&M University, and CH2M Hill.

The GIS foundation for BASINS 4.0 and subsequent versions was provided by Map Window GIS. Map Window GIS was developed by Utah Water Research Laboratory at Utah State University, and is maintained and supported by Idaho State University and Utah State University. Various plug-in elements of BASINS have been developed by a range of entities, as outlined in Table 3.

Table 3. BASINS' plug-in development/contribution

Plug-In	Development/ Contribution
AQUATOX	Eco Modeling and Jonathan Clough of Warren Pinnacle Consulting Inc. developed AQUATOX for U.S.EPA Office of Water.
Automated Geospatial Watershed Assessment (AGWA)	USDA-ARS Southwest Watershed Research Center and the US-EPA National Research Exposure Lab in Las Vegas, NV
Automatic watershed delineation	David Tarboton at Utah State University
Climate Assessment Tool (CAT)	AQUA TERRA developed the tool with for EPA Global Change Research Program (GCRP), in partnership with the EPA Office of Water
DFLOW	US EPA
GenScn	Hydrologic Analysis Software Support Program of the United States Geological Survey, Water Resources Division
GWLF-E	Barry Evans and Ken Corradini of Penn State University
Hourly precipitation data	EarthInfo, Inc
HSPFParm	Tony Donigian, Jr of AQUA TERRA. David Chen (Chinese University of Hong Kong), James Sams (USGS, Pittsburgh), Larry Moore (University of Memphis), Thomas Fontaine (South Dakota School of Mines & Technology) and Scott Wells (Portland State University)

Plug-In	Development/ Contribution
Hydrological Simulation Program - FORTRAN (HSPF)	AQUA TERRA in conjunction with EPA Athens Laboratory and the USGS Office of Surface Water.
OpenSWAT	Jeyakanthan Velupillai and Daniel P. Ames at Idaho State University in cooperation with R. Srinivasan at Texas A&M University
PLOAD	CH2M Hill
SWAT	USDA Agricultural Research Service
SWMM	Low Rossman of the US EPA
USGS Surface Water Statistics (SWSTAT)	U.S. Geological Survey
WASP	Tim Wool at EPA Region 4
Watershed Characterization System (WCS)	Chris Wilson of Wilson Engineering and Tim Wool at EPA Region 4
WDMUtil	Hydrologic Analysis Software Support Program of the United States Geological Survey, Water Resources Division. Note: WDMUtil is a standalone program and cannot be used within BASINS4.1. BASINS4.1 has its own advanced data management system that can also open WDM files

#### Maintenance Status:

Minnesota Pollution Control Agency (MPCA) funded model setup for HSPF and updates to HSPFParm software. BASINS is maintained by EPA Center Exposure Assessment Models (CEAM).

#### MODEL STATUS

BASINS 4.1 is the only version fully supported by EPA. BASINS 4.1 interface has changed from BASINS 4.0, but the main functions have remained the same. BASINS 4.1 includes updates to automatic watershed delineation tools, separation of GenSen and WDMUtil, and includes DFLOW. EPA Region 4 is currently looking at updating BASINS and HSPF.

EPA BASINS 4.11 is a maintenance release containing HSPF 12.2. The current plan is to synch the BASINS and HSPF versioning (BASINS 4.5 and HSPF 12.5) and host them on the EPA web site.

AQUA TERRA (now part of RESPEC) has released BASINS 4.2 that includes HSPF 12.4. BASINS 4.2/ HSPF 12.4 are BETA versions and are not yet available for public release from EPA.

The version history is summarized in 4 and hardware requirements are presented in Table 5.

Table 4. Version history

Version	Release Date	Non-proprietary	Available for download
BASINS 1.0	05/1996	Yes <sup>1</sup>	
BASINS 2.0	01/1999	Yes <sup>1</sup>	
BASINS 3.0	06/2001	Yes <sup>1</sup>	
BASINS 3.1	08/2004	Yes <sup>1</sup>	
BASINS 4.0	03/2007	Yes <sup>2</sup>	
BASINS 4.0 Update 1	11/2007	Yes <sup>2</sup>	
BASINS 4.0 Update 2	08/2008	Yes <sup>2</sup>	

Version	Release Date	Non-proprietary	Available for download
BASINS 4.0 Update 3	05/2010	Yes <sup>2</sup>	
BASINS 4.1	2013	Yes <sup>2</sup>	<a href="#">BASINS 4.1 Download</a>
BASINS 4.1.1	09/2015	Yes <sup>2</sup>	<a href="#">BASINS 4.1 Download</a>
BASINS 4.2	09/2016	Yes <sup>2</sup>	<a href="#">BASINS 4.2 Download</a>

1: Required proprietary ESRI ArcView (prior to v3.0 or less) GIS software

2: Uses Map Windows GIS and is fully non-proprietary

Table 5. Hardware requirements

Hardware/Software	Minimum Requirements	Preferred Requirements
Processor	1GHz processor	2GHz processor or higher
Available hard disk space	2.0 Gb	10.0 Gb
Random access memory (RAM)	512 Mb of RAM plus 2 Gb of page space	1 Gb of RAM plus 2 Gb of page space
Color monitor	16 bit color, Resolution 1024x768	32 bit color, Resolution 1600x1200
Internet Connection	WiFi	DSL or better
Operating system	Windows XP, Vista, Windows 7 and Windows 8	Windows XP, Vista, Windows 7 and Windows 8

The GIS based interface and visualization platform of BASINS is built upon Map Window GIS. It integrates other models and analysis tools.

## ACCESSIBILITY

### User Community Portals

EPA hosts a listserv for the user community, users can request to join here: [BASINS listserv](#) . Users can post messages to the user community or request a search of past messages based on key words.

The [EPA's BASINS support team](#) is available to provide any additional information.

## DOCUMENTATION AND TRAINING MATERIALS

### User Manuals

There is a user manual as well as multiple technical documents that make up the documentation for BASINS.

- [BASINS 4.1 User Manual \(2013\)](#)
- [Technical Note 01: Creating Hydraulic Function Tables \(FTABLES\) for Reservoirs in BASINS \(2007\)](#)
- [Technical Note 02: Two Automated Methods for Creating Hydraulic Function Tables FTABLES \(2007\)](#)
- [Technical Note 03: WinHSPF Simulation Module Matrix \(2007\)](#)
- [Technical Note 04: Incorporating Upstream Flow and Water Quality Time Series in the Source Model \(1999\)](#)
- [Technical Note 05: Using HSPEXP with BASINS \(1999\) \(now replaced with HSPEXP+\)](#)
- [Technical Note 06: Estimating Hydrology and Hydraulic Parameters for HSPF \(2000\)](#)
- [Technical Note 06 Addendum: Additional Notes for HSPF Users \(2000\)](#)
- [Technical Note 07: Matching STORET Parameters with HSPF Output \(2005\)](#)
- [Technical Note 08: Sediment Parameter and Calibration Guidance for HSPF \(2006\)](#)

- [Technical Note 09: Web Based HSPF Toolkit to Support Low Impact Development LID and Other Urban Stormwater Modeling Applications \(2007\)](#)
- [Technical Note 10: Using the BASINS Meteorological Database Version 2006 \(2008\)](#)
- [Technical Note 11: Infiltration BMP Tutorial for HSPF \(2009\)](#)

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#### Training Materials

RESPEC and AECOM are hosted a BASINS/HSPF Training Workshop at Research Triangle Park (RTP), North Carolina in April 2018.

The EPA has developed a series of [BASINS lectures and exercises](#). The lectures and exercises were created for BASINS 4.0, the lectures and exercises are compatible with the BASINS 4.1.

The website hosts 17 lectures including the following topics:

- [Introduction to BASINS and TMDLs](#)
- [Introduction to HSPF and the model application process](#)
- [Watershed delineation](#)
- [Weather data and WDMS](#)
- [Hydrologic processes, parameters and calibration](#)
- [Channel routing in HSPF](#)
- [Operational aspects of HSPF and supporting software](#)
- [Watershed segmentation](#)
- [Snow processes, parameters and calibration](#)
- [Sediment processes, parameters and calibration](#)
- [NPS quality \(PQUAL,IQUAL\) processes, parameters and calibration](#)
- [Instream water quality - temperature, sediment and general constituents](#)
- [AGCHEM processes, parameters and calibration](#)
- [Instream water quality - biochemical reactions](#)
- [Watershed model calibration and validation: issues and procedures](#)
- [Analysis of alternatives: modeling scenarios, BMPs and TMDLs](#)
- [Additional HSPF features](#)

The website also hosts 16 exercises:

- [Building a BASINS project and data download tool](#)
- [Manual and automatic watershed delineation](#)
- [WDM utility](#)
- [Introduction to WinHSPF and GenSen](#)
- [Segmentation](#)
- [WinHSPF hydrology calibration](#)
- [HSPEXP](#)
- [Simulation of snow accumulation and melt](#)
- [Sediment erosion and delivery](#)
- [Sediment transport calibration](#)
- [Bacteria and temperature modeling](#)
- [AHCHEM](#)
- [Nutrient, dissolved oxygen, and algae modeling](#)

- Water quality calibration
- Modeling alternative scenarios, BMPs, and TMDLs
- HSPFParm Tool

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#### Recent Application/Reports

A Watershed Modeling System for Fort Benning, GA Using the US EPA BASINS Framework (2013)

An integrated modeling system for estimating glacier and snow melt driven streamflow from remote sensing and earth system data products in the Himalayas (2014)

Estimating impact of rainfall change on hydrological processes in Jianfengling rainforest watershed, China using BASINS-HSPF-CAT modeling system (2017)

Integration of an energy balance snowmelt model into an open source modeling framework (2015)

Land use and its effects on water quality using the BASINS model (2014)

## BATHTUB

BATHTUB is a steady state, empirically based receiving water model appropriate for simulation of morphologically complex lakes and reservoirs. It applies a series of eutrophication models derived from lake monitoring data from a number of northeastern U.S. lakes to perform steady-state water and nutrient balance calculations that account for advective and diffusive transport, and nutrient sedimentation, as well as internal pollutant sources. Eutrophication-related water quality conditions are predicted by BATHTUB and expressed as total phosphorus, total nitrogen, chlorophyll *a*, transparency, organic nitrogen, ortho-phosphorus, and hypolimnetic oxygen depletion rate. BATHTUB can be configured for simultaneous application to collections or networks of reservoirs to provide regional perspectives on reservoir water quality.

## MODEL DEVELOPER/STEWARD

### Lead developer(s) and affiliation:

The original developer was Dr. William W. Walker for the Environmental Laboratory of the U.S. Army Corps of Engineers (USACE) Waterways Experiment Station (WES).

### Maintenance status:

Dr. David Soballe distributes the Bathtub model on an informal (i.e., unfunded, volunteer) basis. The U.S. Army Corps of Engineers has discontinued any formal maintenance or support for the BATHTUB model. Minnesota Pollution Control Agency (MPCA) hosts the model, but they provide no formal commitment to support the model.

## VERSION INFORMATION

BATHTUB was developed in 1996 and has undergone multiple updates, as summarized in 6.

Table 6. Version History

Version	Release Date	Non-Proprietary
Version 3.2	12/1996	Yes
Version 5.4	12/1998	Yes
Version 6.1	08/2006	Yes
Version 6.2	2014	Yes

## MODEL CODE LANGUAGE

The source code language is Visual Basic and earlier versions were executable through an MS-DOS interface. Version 6 adds a Microsoft Excel interface

## ACCESSIBILITY

### MODEL EXECUTABLE (ALL AVAILABLE VERSIONS)

The model executable is hosted on the Minnesota Pollution Control Agency (MPCA) website ([MPCA BATHTUB download link](#)) and the model is available upon request from David Soballe (contact information below).

### SOURCE CODE (ALL AVAILABLE VERSIONS)

The source code is not publicly distributed.



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#### USER COMMUNITY PORTAL (IF ANY)

There is no community portal.

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#### ACCESS POINTS-OF-CONTACT

Dr. David Soballe email: [dsoballe@gmail.com](mailto:dsoballe@gmail.com)

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#### DOCUMENTATION AND TRAINING MATERIALS

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##### MODEL THEORY DOCUMENTATION

Walker, W.W. (1981). *Empirical Methods for Predicting Eutrophication in Impoundments - Report 1: Data Base Development. Technical Report E-81-9*, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Walker, W.W. (1982) *Empirical Methods for Predicting Eutrophication in Impoundments - Report 2: Model Testing*, prepared for Office, Chief of Engineers, U.S. Army, Washington, D.C., Technical Report E-81-9, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, September 1982. Not available online

Walker Jr, W. W. (1985). *Empirical Methods for Predicting Eutrophication in Impoundments. Report 3. Phase II. Model Refinements*. Report E-81-9, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Walker Jr, W. W. (1985). *Empirical Methods for Predicting Eutrophication in Impoundments. Report 4. Phase III. Applications Manual*. Report E-81-9, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

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##### USER MANUAL

Walker Jr., W.W. (1996) *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual [Version 3]*. Instruction Report W-96-2. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS

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##### EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

[Lake Champlain BATHTUB Model Calibration Report \(PDF\)](#), 2015

[Water quality and hydrology of Silver Lake, Oceana County, Michigan, with emphasis on lake response to nutrient loading \(PDF\)](#), 2015

[Water quality, hydrology, and simulated response to change in phosphorus loading of Butternut Lake, Price, and Ashland Counties, Wisconsin, with Special Emphasis on the Effect of Internal Phosphorus Loading in a Polymictic Lake \(PDF\)](#), 2008

[DRAFT Nutrient TMDLs for Sanibel Slough \(WBIDs 2092F1 and 2092F2\) and Documentation in Support of the Development of Site-Specific Numeric Interpretations of the Narrative Nutrient Criterion \(PDF\)](#), 2017

[Water Quality Improvement Plan for Windmill Lake Taylor County, Iowa \(PDF\)](#), 2016

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##### TRAINING MATERIALS

Sample cases are provided on [William W. Walker's Bathtub main page](#), under the sample cases contents. The sample cases include five instructional cases: (1) single reservoir, spatially averaged, (2) single reservoir, spatially segmented, (3) reservoir embayment, segmented, (4) segmented reservoir, multiple scenario, and (5) collection of

reservoirs, spatially averaged. The sample cases also include four real application files: (1) Keystone Reservoir, Oklahoma - two tributary arms & several segments, (2) Beaver Reservoir, Arkansas - one tributary arm, (3) Lake Memphremagog, Vermont/Canada - natural lake with longitudinal gradient, and (4) Lake Champlain, Vermont/New York / Canada - natural lake with multiple bays & transport channels.

#### RELEVANT LINKS

<http://www.walker.net/bathtub/help/bathtubWebMain.html>

## CE-QUAL-ICM

CE-QUAL-ICM was first developed by the U.S. Army Corps of Engineers' Engineer Research and Development Center (ERDC) as a three-dimensional eutrophication model for Chesapeake Bay and its major tributaries. It continues to be applied for eutrophication studies in rivers, lakes, reservoirs, estuaries and coastal areas around the world. It is capable of simulating biogeochemical cycles, including the aquatic carbon cycle, nitrogen cycle, phosphorus cycle and oxygen cycle as well as physical factors, including salinity, temperature and suspended solids. It does not simulate hydrodynamics. Its technical underpinning is analogous to the finite-volume numerical method and the model simulates the transport and fate of pollutants in well-mixed cells that can be arranged in 1-, 2-, or 3-dimensional configurations. Simulated constituents include algae, carbon, nitrogen, phosphorus, silica, dissolved oxygen, zooplankton, submerged aquatic vegetation, epiphytes, and benthic algae.

## MODEL DEVELOPER/STEWARD

### LEAD DEVELOPER(S) AND AFFILIATION

Dr. Carl Cerco of the U.S. Army Corps of Engineers' (USACE) Engineer Research and Development Center (ERDC).

### MAINTENANCE STATUS AND FUNDING SOURCE

USACE ERDC currently maintains and supports ongoing model development.

## MODEL STATUS

### CURRENT MODEL VERSION AND YEAR OF RELEASE

Version 1.0 is the original version developed for Chesapeake Bay in 1992. The current generally available standard distribution version is Version 1.1, (released 11/17/2015). A library of additional sub-models developed during subsequent CE-QUAL-ICM applications is available but not all submodules are available with Version 1.1, which only comes with the sediment diagenesis submodule. One may request the other available submodules (filter feeding benthos, toxics, submerged aquatic vegetation and carbon cycle) directly from the Chesapeake Bay Program (Lewis Linker, [LLinker@chesapeakebay.net](mailto:LLinker@chesapeakebay.net)).

A newly developed "ICM-Lite" version is designed to run on a PC and with an excel user interface. This is available from [Jodi.L.Ryder@usace.army.mil](mailto:Jodi.L.Ryder@usace.army.mil).

### MODEL CODE LANGUAGE

FORTRAN

### PREVIOUS VERSIONS STILL AVAILABLE FOR DOWNLOAD AND YEAR OF RELEASE

None prior to version 1.1

## ACCESSIBILITY

### MODEL EXECUTABLE AND SOURCE CODE

The basic version of ICM (version 1.1, 11/17/2015) is available at no cost. The standard distribution version is available from: <https://sourceforge.net/projects/cequalicm/?source=directory>. (Version 1.1; 11/17/2015).

The source code is open to users. The distribution packet includes FORTRAN code, a compiled version executable on a Windows PC, and a user's guide.

The full featured version is housed on a Corps of Engineers server that is not accessible to the general public. As noted above this version may be obtained by contacting the Chesapeake Bay Program at the contact listed.

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#### USER COMMUNITY PORTAL

The Chesapeake Community Modeling Program provides a forum for discussion of the open source models used for Bay applications, including CE-QUAL-ICM; it is not currently active and there is no forum specifically devoted to discussion of the CE-QUAL-ICM model. <http://ches.communitymodeling.org/models.php>

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#### ACCESS POINTS-OF-CONTACT:

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##### Standard Version

AVAILABLE WITH DOCUMENTATION AT THE FOLLOWING LINK:

<https://sourceforge.net/projects/cequalicm/?source=directory>.

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##### Full Featured Version

Chesapeake Bay Program

Dr. Lewis Linker, [LLinker@chesapeakebay.net](mailto:LLinker@chesapeakebay.net)

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##### ICM-Lite Version

United States Corps of Engineers

Jodi Ryder, [Jodi.L.Ryder@usace.army.mil](mailto:Jodi.L.Ryder@usace.army.mil)

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##### General Information and Questions

Dr. Carl F. Cerco, PE., RETIRED.

Email: [Carl.Cerco@outlook.com](mailto:Carl.Cerco@outlook.com)

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#### DOCUMENTATION AND TRAINING MATERIALS

A general [Fact Sheet](#) is available on the USACE webpage. Other general information is available on the Chesapeake Community Modeling Program [webpage](#). Both contain outdated version information.

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#### MODEL THEORY DOCUMENTATION (INCLUDING MODEL VERSION AND PUBLICATION YEAR)

The existing available user manual is for version 1.0 (1995). Additional capabilities have been added to ICM since then and the corresponding theoretical documentation provided in the following references:

Cerco, C., and Cole, T. 1993. "Three-dimensional eutrophication model of Chesapeake Bay," *Journal of Environmental Engineering*, 119(6), 1006-1025.

Cerco, C., and Moore, K. 2001. "System-wide submerged aquatic vegetation model for Chesapeake Bay," *Estuaries*, 24(4), 522-534.

Cerco, C., and Noel, M. 2004. "Managing for water clarity in Chesapeake Bay," *Journal of Environmental Engineering*, 130(6), 631-642.

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#### USER MANUAL (INCLUDING MODEL VERSION AND PUBLICATION YEAR)

Available with download of the model and also at the following link: [User's Guide to the CE-QUAL-ICM Three-Dimensional Eutrophication Model Release Version 1.0 \(1995\) by Carl F. Cerco and Thomas Cole.](#)

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#### RECENT PUBLICATIONS OF MODEL APPLICATIONS

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CERCO, CARL F., AND MARK R. NOEL (2010). [THE 2002 CHESAPEAKE BAY EUTROPHICATION MODEL](#). U. S. ARMY CORPS OF ENGINEERS WATERWAYS EXPERIMENT STATION, VICKSBURG, MS. PREPARED FOR THE CHESAPEAKE BAY PROGRAM OFFICE, U.S. ENVIRONMENTAL PROTECTION AGENCY, ANNAPOLIS, MD. EPA 903-R-04-004. JULY 2004.

Cerco, Carl F., Mark R. Noel, and Sung-Chan Kim (2004). [Three-Dimensional Eutrophication Model of Lake Washington](#), Washington State Environmental Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, MS. ERDC/ELTR-04-12. August 2004.

Cerco, C., Noel, M., and Kim, S-C. (2006). ["Three-dimensional management model for Lake Washington: \(II\) Eutrophication modeling and skill assessment,"](#) Journal of Lake and Reservoir Management, 22(2), 115-131.

Cerco, C., and Noel, M. (2007). ["Can oyster restoration reverse cultural eutrophication in Chesapeake Bay?"](#) Estuaries and Coasts, 30(2), 331-343.

Dortch, Mark S., Mansour Zakikhani, Mark R. Noel, and Sung-Chan Kim (2007). [Application of a Water Quality Model to Mississippi Sound to Evaluate Impacts of Freshwater Diversions](#). U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS

St. Johns River Water Management District (2012). [Water Supply Impact Study Technical Publication SJ2012-1](#). St. Johns River Water Management District, Palatka, FL.

St. Johns River Water Management District (2012). [Water Supply Impact Study Appendix 8.D. CE-QUAL-ICM Setup, Calibration and Withdrawal Scenario Results](#). John C. Hendrickson, SJRWMD St. Johns River Water Management District, Palatka, FL.

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#### TRAINING MATERIALS

- none

## CE-QUAL-W2

CE-QUAL-W2, commonly referred to as W2, is a 2-dimensional (vertical/longitudinal) hydrodynamic and water quality model. It is configured as a user defined grid and its mathematical structure is based on a set of differential equations that define conservation of mass and energy in each horizontal layer. The model includes variable cell spacing allowing for greater resolution where needed with simulation algorithms based on hydrostatic approximation (i.e. negligible vertical accelerations) and eddy coefficients used to simulate turbulence. Also included are numerical algorithms for pipe, weir, spillways, and pump flow. Simulated water quality includes nutrients, eutrophication kinetics, and a single algal compartment. General quality constituents can also be simulated using user-defined decay rates, settling rates, and temperature correction coefficients. It is best suited for long, narrow rivers, lakes, reservoirs and estuaries because it assumes lateral homogeneity.

## MODEL DEVELOPER/STEWARD

### LEAD DEVELOPER(S) AND AFFILIATION

Thomas Cole, of the U.S. Army Corps of Engineers (USACE) originally developed W2 and the Corps provided early maintenance and development support for W2. While they have done so in the past, presently, the Corps does not provide support for model maintenance. Dr. Scott Wells, director of the [Water Quality Research Group \(WQRG\)](#) at Portland State University (PSU) continues to maintain the code internally at PSU. The work is supported by research grants and CE-QUAL-W2 training contracts (personal communication). Dr. Wells indicated that his group has received additional funds beginning in fall 2018 (with further funding anticipated) to continue updating and maintaining the code for the Corps.

### MAINTENANCE STATUS AND FUNDING SOURCE

A [fact sheet on the USACE webpage](#) (undated, accessed 10/11/2017) is outdated, indicating the current version of W2 is 3.71. The current version is version 4.1. It was released October 3, 2017.

PSU provides the newest version of W2 on their web page, which notes that they do not receive support from USACE for model support, maintenance or upgrades. Contributions are accepted on the webpage to help support continued model maintenance, bug fixes and updates.

## MODEL STATUS

All available versions of W2 are non-proprietary and the source code is publicly available.

### CURRENT MODEL VERSION AND YEAR OF RELEASE

The current version is 4.1 (October 3, 2017), available [here](#), includes a registration page, download of source code, model release notes, executable, User Manual, documentation, example problems and reports.

### OTHER MODEL VERSIONS

Older versions of W2 including versions 3.1, 3.2, 3.5, 3.6, and 3.7 are also available on the [PSU model webpage](#); however they are no longer actively supported. The download packages are similar to version 4.1. The [‘History’](#) link on the model webpage provides a detailed description of the differences between all versions of W2.

### MODEL CODE LANGUAGE

FORTRAN

## ACCESSIBILITY

The W2 model is in the public domain and its source code is available for download. <http://www.cee.pdx.edu/w2>

## USER COMMUNITY PORTAL

[Water Quality Research Group](#) (WQRG) at Portland State University hosts a user forum at this [LINK](#). Registration is required for posting messages.. Alternatively, access to the forum (i.e., read access) may be granted by emailing the site administrator ([bergerc@cecs.pdx.edu](mailto:bergerc@cecs.pdx.edu)) with full contact information (name, title, organization, email and phone number) or at the following [LINK](#).

There is also a [blog](#) where model updates and code changes are described.

## ACCESS POINTS-OF-CONTACT

Contacts associated with the Army Corps of Engineers as well as PSU are provided below.

Topic	Contact Information
PSU W2	Scott Wells: Professor Department of Civil and Environmental Engineering Portland State University Phone: (503) 725-4276 Fax (503) 725-5950 E-mail: <a href="mailto:wells@pdx.edu">wells@pdx.edu</a>
	Chris Berger: Research Assistant Professor Department of Civil and Environmental Engineering Portland State University Phone: (503) 725-3048 Fax : (503) 725-5950 E-mail: <a href="mailto:berger@pdx.edu">berger@pdx.edu</a>

## DOCUMENTATION AND TRAINING MATERIALS

A general [FACT SHEET](#) is available on the USACE website; however the version information is not current.

## MODEL THEORY DOCUMENTATION

Cole, T.M., and Wells, S. A. (2017) "CE-QUAL-W2: A two-dimensional, laterally averaged, hydrodynamic and water quality model, version 4.1," Department of Civil and Environmental Engineering, Portland State University, Portland, OR.

## USER MANUAL

[Version 4.1 User's Manual](#)—October 2017

## EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS (5 MOST RECENT PAPERS/REPORTS)

- Bowen, J., and Hieronymus, J. (2003). "A CE-QUAL-W2 Model of Neuse Estuary for Total Maximum Daily Load Development." *Journal of Water Resources Planning and Management*, 129(4), 283-294.
- O'Donnell, S., Gelda, R., Effler, S., and Pierson, D. (2011). "Testing and Application of a Transport Model for Runoff Event Inputs for a Water Supply Reservoir." *Journal of Environmental Engineering*, 137(8), 678-688.
- Singleton, V., Jacob, B., Feeney, M., and Little, J. (2013). "Modeling a Proposed Quarry Reservoir for Raw Water Storage in Atlanta, Georgia." *Journal of Environmental Engineering*, 139(1), 70-78.

Wells, S. A., Wells, V. I., and Berger, C. (2012). "Impact of Phosphorus Loading from the Watershed on Water Quality Dynamics in Lake Tenkiller, Oklahoma, USA," Proceedings World Environmental and Water Resources Congress, EWRI, ASCE, Albuquerque, NM, pp. 888-899.

Wells, V. I. and Wells, S. A. (2012). "CE-QUAL-W2 Water Quality and Fish-bioenergetics Model of Chester Morse Lake and the Cedar River," Proceedings World Environmental and Water Resources Congress, EWRI, ASCE, Albuquerque, NM, pp. 2756-2767

Zhang, H., Culver, D. A., and Boegman, L. (2008). "A two-dimensional ecological model of Lake Erie: Application to estimate dreissenid impacts on large lake plankton populations." *Ecological Modelling*, 214(2-4), 219-241.

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#### TRAINING MATERIALS

PSU periodically holds a 4 ½ day Workshop on W2. The next is scheduled for June 18-22, 2018 in Portland, OR.

An Internet search revealed a Wiki page for first time users, source not known. (2013)



## CORMIX

CORMIX is a mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. The system emphasizes the role of boundary interaction to predict steady-state mixing behavior and plume geometry.

CORMIX contains systems to model discharges where initial mixing zone characteristics are desired. Discharge types that can be modeled include power plant cooling waters, desalinization facility or drilling rig brines, and municipal wastewater. The effluents considered may be conservative, non-conservative, heated, brine discharges or contain suspended sediments. CORMIX can be applied across a variety of waterbodies ranging from estuaries, deep oceans, rivers, to stratified reservoirs and lakes. CORMIX makes near-field and far-field plume trajectory, shape, concentration, and dilution predictions and visualizations within these waterbodies.

## MODEL DEVELOPER/STEWARD

CORMIX development began in 1986 with Dr. Robert Doneker at Cornell University under a contract with the U.S. Environmental Protection Agency (Environmental Research Laboratory, Athens, GA; Dr. Thomas Barnwell, Program Officer).

CORMIX is no longer distributed or supported by the U.S. EPA. Information on a Windows version of CORMIX is available at [cormix.info](http://cormix.info). CORMIX software is licensed and distributed solely by MixZon Inc. Contact MixZon Inc. or Dr. Robert Doneker ([doneker@ese.ogi.edu](mailto:doneker@ese.ogi.edu)) of Oregon Graduate Institute (OGI) Department of Environmental Science and Engineering for technical information and support.

## MODEL STATUS

The current model versions are 10.0G (General Release), 10.0GT (Advanced Tools), 10.0GTH (Advanced Tools Hydraulics), 10.0GTS (Advanced Tools Sediment), 10.0 GTD (Advanced Tools Design), and 10.0 GTR\* (Research Tools Release). The feature comparison of the different versions of CORMIX v10.0 can be found at <http://www.mixzon.com/sales/featcomp.php>.

CORMIX v10.0 was released in 2016 and is available for purchase and download at [www.mixzon.com/downloads/](http://www.mixzon.com/downloads/). Previous versions are not available for download.

CORMIX is composed of mathematical models to predict geometry and dilution characteristics of mixing zones within computer-aided-design (CAD) interface. CORMIX is coded in NEXPERT object, an “expert systems shell”, C++, and FORTRAN. NEXPERT is for the logical reasoning and FORTRAN for mathematical computations.

The version history of the CORMIX model is provided in Table 7.

Table 7. Model versions for CORMIX

Version	Developer	Release Date	Proprietary/ Non-Proprietary
DOS Version 1.00	Cornell University	1989	Non-Proprietary
DOS Version 2.00	Cornell University	1992	Non-Proprietary
DOS Version 2.10	Cornell University	1993	Non-Proprietary
DOS Version 3.00	Cornell University	1994	Non-Proprietary
DOS Version 3.10	Cornell University	1995	Non-Proprietary
DOS Version 3.20	Cornell University	1996	Non-Proprietary
CORMIX-GI Version 4.00	Oregon Graduate Institute	1999	Proprietary
CORMIX-GI Version 4.1E, 4.1G, 4.1GT, 4.1GTR	Oregon Graduate Institute	2000	Proprietary

Version	Developer	Release Date	Proprietary/ Non-Proprietary
CORMIX Version 4.2E, 4.2G, 4.2GT, 4.2GTR	MixZon, Inc.	2002	Proprietary
CORMIX Version 4.3E, 4.3G, 4.3GT, 4.3GTR	MixZon, Inc.	2004	Proprietary
CORMIX Versions 5.0E, 5.0G, 5.0GT, 5.0GTS, 5.0GTR	MixZon, Inc.	2007	Proprietary
CORMIX Versions 6.0E, 6.0G, 6.0GT, 6.0GTS, 6.0GTD, 6.0GTR	MixZon, Inc.	2009	Proprietary
CORMIX Versions 7.0E, 7.0G, 7.0GT, 7.0GTH, 7.0GTS, 7.0GTD, 7.0GTR	MixZon, Inc.	2011	Proprietary
CORMIX Versions 8.0E, 8.0G, 7.0GT, 8.0GTH, 8.0GTS, 8.0GTD, 8.0GTR	MixZon, Inc.	2012	Proprietary
CORMIX Versions 9.0E, 9.0G, 9.0GT, 9.0GTH, 9.0GTS, 9.0GTD, 9.0GTR	MixZon, Inc.	2014	Proprietary
CORMIX Versions 10.0E, 10.0G, 10.0GT, 10.0GTH, 10.0GTS, 10.0GTD, 10.0GTR	MixZon, Inc.	2016	Proprietary

## ACCESSIBILITY

The model executable can be downloaded from [www.mixzon.com/downloads/](http://www.mixzon.com/downloads/) once a MixZon user's account is created. A User Name and Password is required to download the model. The minimum system requirements are Windows Vista/7/8/8.1/10, active internet connection with access to [www.mixzon.com](http://www.mixzon.com), 1 GHz or faster 32-bit or 64-bit processor, 1 or 2 GB RAM, and minimum of 250 MB free hard disk space (<http://www.cormix.info/releaseinfo100.php>).

## SOURCE CODE

The source code is not available.

## USER COMMUNITY PORTAL

There is no user community portal. However, MixZon offers CORMIX Technical Support via a subscription service called CorSupport ([www.mixzon.com/support/](http://www.mixzon.com/support/)). Current software licensing is required for access to CorSupport.

## DOCUMENTATION AND TRAINING MATERIALS

### MODEL THEORY DOCUMENTATION

The user's MixZon user name and password allows the download of model theory documentation from [www.mixzon.com/downloads/](http://www.mixzon.com/downloads/) including:

CORMIX1 Technical Report (1990) Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Submerged Single Port Discharges (CORMIX1) - [EPA/600/3-90/012]

CORMIX2 Technical Report (1991) CORMIX2:An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges - [EPA/600/3-91/073]

CORMIX3 Technical Report (1996) CORMIX3:An Expert System for Mixing Zone Analysis And Prediction of Buoyant Surface Discharges - [CR 818527]

CORMIX Tidal Applications Technical Report (1995) Buoyant Discharges into Reversing Ambient Currents - Jonathan D. Nash Thesis

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## USER MANUAL

The CORMIX User's Manual Rev. 10.0.3.0 (2017) is available for download in Adobe Acrobat - PDF format using the user's MixZon account information. The User's Manual is also part of the CORMIX installation ([www.mixzon.com/downloads/](http://www.mixzon.com/downloads/)). The citation for the user's manual is:

Doneker L. R. and H.G. Jirka. 2014. CORMIX User Manual. A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters. EPA-823-K-07-001 (December 2007).

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## EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

[Environmental Planning, Prediction and Management of Brine Discharges from Desalination Plants \(2010\)](#)

[Effect of Thermal Discharge of Cool Water Outfall from Liquefied Natural Gas \(LNG\) Plant into Sea Using CORMIX \(2013\)](#)

Yang, Y., Y. Liu, Y. Qiao, F. Liu, C. Zhang and B. Wang. (2013). *Near Field Simulation of Low Level Waste Water Released from Nuclear Power Plants in Rivers through Surface by CORMIX*. Advanced Materials Research, Vols. 807-809, pp. 113-117.

Yang, Y., Y. Qiao, X. Pan, Y. Liu, F. Liu, A. Zhang, B. Wang and C. Zhang. (2014). *Research of Water Body Diffusion Condition in Near Field of Inland Nuclear Power Plants in China*. Advanced Materials Research, Vols. 955-959, pp. 1722-1725.

[Simulation of Sediment Discharge during an Outfall Dredging Operation \(2016\)](#)

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## TRAINING MATERIALS

MixZon Inc. provides a web-based, online CORMIX training series that covers introductory CORMIX topics (<http://www.mixzon.com/training/>). The training series consists of four two-hour Introductory Classes that focuses on regulatory background, definition of Mixing Zones, Mixing Processes and the CORMIX Mixing Zone model application and use with illustrative case studies. In addition to the online training course, MixZon offers CORMIX Technical Support via a subscription service called CorSupport. Current software licensing is required for access to CorSupport.

## EFDC

The Environmental Fluid Dynamics Code (EFDC) is a public domain, open source, linked hydrodynamic and water modeling system, which also includes modules for sediment transport and fate and transport of toxic contaminants fully integrated in a single source code. Model simulations can be fully coupled where hydrodynamics, sediment, and contaminant transport are executed simultaneously or be done using saved hydrodynamic transport data. EFDC can represent water bodies in one, two and three dimensions using a finite difference methodology. Model cells are represented using a curvilinear or Cartesian grid with two options for vertical cell spacing: Sigma-z or GVC (general vertical coordinate). Water column transport includes 3-dimensional advection and vertical and horizontal turbulent diffusions. EFDC also incorporates a eutrophication water quality model, functionally equivalent to CE-QUAL-ICM and can represent multiple size classes of cohesive and non-cohesive sediments, associated deposition and resuspension processes, and bed geomechanics. Toxics are transported as both dissolved and sediment associated in the water column and bed. Other model features include representation of drying and wetting, hydraulic structures, vegetation resistance, and Lagrangian particle tracking.

## MODEL DEVELOPER/STEWARD

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### Lead developer(s) and affiliation:

The late Dr. John Hamrick originally developed EFDC while at the Virginia Institute of Marine Science, funded with state legislatively directed research funds. Further support was provided by the U.S. Environmental Protection Agency and the National Oceanic and Atmospheric Administration's Sea Grant Program. After Dr. Hamrick joined in the 1990's, Tetra Tech has been a major focus for continued development of EFDC—both from continued EPA funding as well as through a variety of additional projects throughout the country. Tetra Tech continues to support the use and enhancement of EFDC through individual, project-specific customizations.

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### Maintenance status:

There is no current federally supported program to maintain, support or enhance the model. Project- and client-specific efforts to customize the model have resulted in multiple customized versions developed by various entities among government, academia and consulting firms.

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### Funding source:

None ongoing for the EPA version of EFDC.

## VERSION INFORMATION

For purposes of this summary, the publicly available, EPA version of EFDC will be referred to as EPA-EFDC. Other entities have also developed versions of EFDC based on the 2007 EPA-EFDC. These versions are technically “newer” versions and have undergone various customizations, sometimes significant, depending on specific program needs. For example, the Philadelphia Water Department maintains its own version of EFDC, which was based on the 2007 EPA-EFDC version but has been significantly customized to support the needs of the department. Likewise, the St. Johns Water Management District in Florida also maintains a version of EFDC for the St. Johns River.

Sandia National Laboratories<sup>1</sup> developed SNL-EFDC, an open-source tool to support the marine renewable-energy industry by enabling simultaneous evaluation of array power production and environmental effects. They

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<sup>1</sup> Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration.

subsequently incorporated the module into an open-source version of the DELFT-3D application called SNL-DEFLT-3D-CEC.

Dynamic Solutions-International (DSI), developed a Windows-based GUI (interface) for pre- and post-processing of the Environmental Fluid Dynamics Code (EFDC). The interface is commercially known as EFDC-Explorer and their version of the EFDC model is called EFDCPlus. DSI's version of EFDC includes a multi-thread function as well as new variables such as CO<sub>2</sub>. DSI's website provides links for downloading EFDC\_Plus as well as the EPA-EFDC version. The user must register to download all files from the website. EFDCPlus, EFDC-Explorer and the grid generator are all proprietary. They provide the source code for only their single-thread version to licensees upon request.

In recent years, Tetra Tech developed Visual EFDC (VEFDC), a user-graphical interface for creating and editing curvilinear orthogonal grids for EFDC as well as for creating and manipulating input data files and model output results. VEFDC is not open-source but Tetra Tech distributes the interface to clients and upon request. In addition to the above EFDC model versions and GUIs, other pre and post processing GUI tools for EFDC are commercially available (e.g., grid generation tools and post processing tools to support various graphics packages). Funding to support development of these tools has come from various sources so they are not all necessarily publicly available or their source code may not be available.

The version history of EPA-EFDC and others is summarized in Table 8. All of the non-EPA versions are derived from the EPA version. Executables are presented in Table 9.

Table 8. Draft Version History

Version	Release	Non-	Developer	Operating	Code	Available
EPA_EFDC v 1.1	09/2007	Yes	Tetra Tech Inc.	Windows 95/98/NT/2K/XP	FORTTRAN	Yes
EFDC_Plus 8.2	06/02/2017	No	DSI	XP, Vista, Win7, Win8, and Win10 in either 32 or 64 bit; Linux with windows emulator	FORTTRAN	To clients
EFDC_Plus 8.1	09/08/2016	No	DSI		FORTTRAN	To clients
EFDC_EPA	12/01/2010	Yes, must register	Tetra Tech, Inc.	??	FORTTRAN	Yes
SNL-EFDC 1 0.0 (Beta)	10/20/2015	Yes	Sandia National Laboratories	??	FORTTRAN	Yes

Table 9. Executables

Version	Release Date	Download Page
EPA_EFDC v 1.1	09/2007	<a href="https://www.epa.gov/exposure-assessment-models/environment-fluid-dynamics-code-efdc-download-page">https://www.epa.gov/exposure-assessment-models/environment-fluid-dynamics-code-efdc-download-page</a>
EFDC_Plus for	06/02/2017	<a href="http://www.efdc-explorer.com/downloads/efdc-dsi-model.html">http://www.efdc-explorer.com/downloads/efdc-dsi-model.html</a>
EFDC_Explorer	07/04/2017	<a href="http://www.efdc-explorer.com/downloads/efdc-explorer.html">http://www.efdc-explorer.com/downloads/efdc-explorer.html</a>
CVLGrid 1.1	10/17/2016	<a href="http://www.efdc-explorer.com/downloads/cvlgid.html">http://www.efdc-explorer.com/downloads/cvlgid.html</a>
SNL-EFDC 1 0.0	10/20/2015	<a href="https://sourceforge.net/projects/snl-efdc/?source=navbar">https://sourceforge.net/projects/snl-efdc/?source=navbar</a>
VEFDC 2.0.0.20	8/21/2017	Contact <a href="mailto:brian.watson@tetratech.com">brian.watson@tetratech.com</a>
The VEFDC setup package includes the GUI as well as the EFDC executable and user manuals.		

## ACCESSIBILITY

### EPA\_EFDC

Model executable is downloadable from EPA <http://www2.epa.gov/exposure-assessment-models/efdc>

Source code is available from EPA's Center for Exposure Assessment Modeling (CEAM).

Phone: 706-355-8403

E-mail: [ceam@epa.gov](mailto:ceam@epa.gov)

### EFDC\_PLUS/EXPLORER

Model executables (all available versions) available at <http://www.efdc-explorer.com/downloads/>

Source code is not available for the multi-thread version of the EFDC\_Plus model. Otherwise, source code is provided upon request to clients and users with a paid license.

### SNL-EFDC

Executable and source code are available. Must submit order request--

<https://www.osti.gov/scitech/biblio/1242511> or download from the following location:

<https://sourceforge.net/projects/snl-efdc/?source=navbar>

Possible Contact: Jesse Roberts – [jdrober@sandia.gov](mailto:jdrober@sandia.gov)

### VEFDC

Installation package available upon request.

Contact: [brian.watson@tetratech.com](mailto:brian.watson@tetratech.com)

## DOCUMENTATION AND TRAINING MATERIALS

### User community portals

- EPA-EFDC –A Yahoo user group was active under Dr. Hamrick; it no longer exists.
- Dynamic Solutions-International hosts two user forums for the EFDC Explorer application and one for EFDC: <http://www.efdc-explorer.com/forums/>
- SNL-EFDC – none
- VEFDC - none

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## User Manuals and Theoretical Documentation

### Multiple Theoretical and Academic EFDC References:

[https://www.epa.gov/sites/production/files/documents/EFDC\\_References.pdf](https://www.epa.gov/sites/production/files/documents/EFDC_References.pdf)

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## EPA-EFDC

A user manual and three separate volumes comprise the theoretical and computational documentation for EPA-EFDC.

- [EFDC user manual EPA ver 101 \(PDF\)](#)
- [EFDC Hydrodynamics Mass Transport Manual \(PDF\)](#) (60 pp, 411 K)
- [EFDC Sediment Contaminant Transport Manual \(PDF\)](#) (96 pp, 631 K)
- [EFDC Water Quality Manual \(PDF\)](#) (90 pp, 606 K)

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## EFDC\_Plus/Explorer

Documentation is available here: <http://www.efdc-explorer.com/downloads/efdc-dsi-model.html>

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## SNL-EFDC

- [Model User Manual](#)
- [Sediment Transport User Manual](#)
- [pH Effects User Manual](#)

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## TRAINING MATERIALS/COURSES

- EPA-EFDC
  - EPA's modeling workgroup sponsored the "Introduction to EFDC" webinar in February 2017 (available at <https://www.epa.gov/tmdl/tmdl-modeling>)
  - EPA Region 3 supported a multi-day training that included EFDC topics (2010)
    - Overview of Receiving Water Modeling
    - Introduction to EFDC
    - Grid Generation
    - EFDCView Preprocessor/Model Setup
    - EFDC
    - Linkage to LSPC
    - EFDCView Model setup
    - Hydrodynamic Calibration
  - EPA Region 6 sponsored a Dissolved Oxygen modeling training in which EFDC was discussed but QUAL2K was the main model focus (2007)
- EFDC-Explorer – 32 hour training course offered. ([link](#))
- SNL-EFDC – none
- VEFDC - none

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## RECENT APPLICATIONS/REPORTS

Camacho, R. A., Martin, J. L., Watson, B., Paul, M. J., Zheng, L., & Stribling, J. B. (2014). Modeling the factors controlling phytoplankton in the St. Louis Bay Estuary, Mississippi and evaluating estuarine responses to nutrient load modifications. *Journal of Environmental Engineering*, 141(3), 04014067.

Chen, Yan, R. Zou, H. Su , S. Bai , M. Faizullabhoy , Y. Wu and H Guo. (2017). Development of an Integrated Water Quality and Macroalgae Simulation Model for Tidal Marsh Eutrophication Control Decision Support. *Water* 2017, 9, 277; doi:10.3390/w9040277.

Tetra Tech. (2015). South Saskatchewan River In-Stream Water Quality Model. Prepared for Alberta Environment and Parks, Calgary, Alberta. December 2015.

Tetra Tech. (2015). Final Report: Hydrodynamic and Water Quality Modeling Report for the Savannah Harbor, Georgia. Prepared for Department of the Army, Savannah District, Corps of Engineers. Final Report, Version 3; October 30, 2015.

Tetra Tech. (2014). Sheep River In-Stream Water Quality Model Modelling. Prepared for Alberta Environment and Sustainable Resource Development, Calgary, Alberta. June 2014.



## HAWQS

The Hydrologic and Water Quality System (HAWQS) is a web-based interactive water quantity and quality modeling tool that uses the Soil and Water Assessment Tool (SWAT) as its core model. HAWQS provides users with interactive web interfaces and maps; pre-loaded input data; SWAT outputs that include tables, charts, and raw output data; and online development, execution, and storage of a user's modeling projects.

## MODEL DEVELOPER/STEWARD

The U. S. Environmental Protection Agency (EPA) Office of Water supports and provides project management and funding for HAWQS. The Texas A&M University Spatial Sciences Laboratory and EPA provide ongoing technical support including system design, modeling, and software development.

## MODEL STATUS

HAWQS Version 1.0 is a non-proprietary modeling tool that was released in September 2017. Future versions will be released based on user needs. There are no previous versions.

The model code language for the SWAT model within HAWQS is FORTRAN.

## ACCESSIBILITY

HAWQS is run entirely on a server, therefore personal computing requirements are minimal. HAWQS requires a web browser, such as the latest version of Chrome, Firefox, or Safari, Internet Explorer 11 or Microsoft Edge.

HAWQS can be accessed at [epahawqs.tamu.edu/](http://epahawqs.tamu.edu/).

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## SOURCE CODE

The source code for the SWAT model used in HAWQS is available for download at [swat.tamu.edu/software/swat-executables/](http://swat.tamu.edu/software/swat-executables/).

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## USER COMMUNITY PORTAL

There is no HAWQS community portal. For assistance with account settings and system errors, users can contact [eco.web@tamu.edu](mailto:eco.web@tamu.edu). For assistance with training and use cases, users can contact [hawqs@epa.gov](mailto:hawqs@epa.gov).

## DOCUMENTATION AND TRAINING MATERIALS

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### MODEL THEORY DOCUMENTATION

HAWQS does not have its own model theory documentation. All model theory documentation for the SWAT model can be found at [swat.tamu.edu/documentation/](http://swat.tamu.edu/documentation/). The documentation includes *Soil and Water Assessment Tool Theoretical Documentation* for SWAT versions 2000, 2005 and 2009 (Neitsch et al. 2002, 2005 and 2011). There is also *Input/Output File Documentation* for SWAT versions 2005, 2009 and 2012 (Neitsch et al. 2004 and 2011; Arnold et al. 2012).

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### USER MANUAL

The *HAWQS v1.0 User Guide* was released in September 2017 and can be downloaded [epahawqs.tamu.edu/](http://epahawqs.tamu.edu/).

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### EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

Since HAWQS is such a new modeling tool (released September 2017), there are not many publications of model applications. The following two papers were found.

Fant, C., R. Srinivasan, B. Boehlert, L. Rennels, S. Chapra, K. M. Strzepek, J. Corona, A. Allen and J. Martinich. (2017). Climate Change Impacts on US Water Quality Using Two Models: HAWQS and US Basins. *Water* 9 (118).

Yen, H., Daggupati, P., White, J.M., Srinivasan, R. Gossel, A., Wells, D., and Arnold, G. J. (2016). Application of Large-Scale, Multi-Resolution Watershed Modeling Framework Using the Hydrologic and Water Quality System (HAWQS). *Water* 8 (164).

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#### TRAINING MATERIALS

There are no training materials available besides the User Manual ([epahawqs.tamu.edu/](http://epahawqs.tamu.edu/)) and step-by-step use-cases. For assistance with training, users can contact [hawqs@epa.gov](mailto:hawqs@epa.gov).

## HSPF

The Hydrologic Simulation Program FORTRAN (HSPF) is a comprehensive model for the simulation of watershed hydrology and water quality for both conventional pollutants and toxic chemicals. It enables simulation of both land based runoff, temperature, and pollutant loading with instream hydraulic and pollutant fate and transport processes in 1-dimensional stream channels. Watershed hydrology simulations are based on the Stanford Watershed Model and consists of a water balance method that defines the water storage for surface and soil layers. Water storage is modified by interception, infiltration, evapotranspiration, and losses to inactive groundwater with outflows simulated from surface and subsurface (interflow and groundwater outflow) layers. Sediment is simulated as cohesive (silt and clay) and non-cohesive (sand) fractions with loading based on detachment/scour and transport algorithms. Other pollutant loads can be simulated generally using build-up washoff functions and instream transport and fate processes or using agricultural and eutrophication modules that explicitly represent the application, transformation, interaction, and fate of nutrients, phytoplankton, gases, pH, and pesticides. HSPF also includes a special action block for simulating management activities.

## MODEL DEVELOPER/STEWARD

HSPF was originally developed by Crawford et al. (1966) as the Stanford Watershed Model—a hydraulic and hydrologic model. Development of a FORTRAN version, which included water quality processes, was funded by the Athens, GA, Research Lab of the U.S. Environmental Protection Agency and released in 1974 under its current name Hydrologic Simulation Program, Fortran (HSPF). In the 1980s, pre- and post-processing software, algorithm enhancements, and use of the USGS binary Watershed Data Management (WDM) system were developed jointly by the U.S. Geological Survey (USGS) and EPA. This included work performed by HydroComp, Inc. and included the development of the original user's manual as part of the Version 5.0 release. Since 1980, all model code changes have been maintained by AQUA TERRA Consultants (now a subsidiary of RESPEC), under contract with EPA and USGS. During the mid to late 1990s, Tetra Tech, Inc., under contract with EPA developed the BASINS system and Non-point Source Model (NPSM), resulting in the first Windows-based interface for the HSPF model.

The current supported model release is Version 12.2, distributed with BASINS 4.1 as the WinHSPF model interface. WinHSPF is a standalone application, however, and can be run outside of the BASINS platform. The version 12 series includes a number of new options and enhancements, as well as bug fixes. AQUA TERRA Consultants also offer Version 12.4 (containing increased array bounds and minor bug fixes) as a standalone download, although it is still a beta version under internal peer review. HSPF Version 12.4 or 12.5 is anticipated to be included in the forthcoming release of BASINS 4.5.

## MODEL STATUS

HSPF Version 12.2 is distributed with BASINS 4.1, with an initial release in 2013. WinHSPF Version 3.0 beta and Version 2.3 are distributed with BASINS 4.1 as GUI's for the underlying HSPF algorithms and can be downloaded at <https://www.epa.gov/exposure-assessment-models/basins-download-and-installation>.

The HSPF algorithms are coded in FORTRAN 77.

HSPF Version 11.0, released in 1996 is available from USGS at <https://water.usgs.gov/software/HSPF/>

All versions of HSPF are nonproprietary.

## ACCESSIBILITY

Model executables for the WinHSPF versions distributed with BASINS 4.1 are available as Version 2.3 and Version 3.0, both of which run HSPF Version 12.2. HSPF Version 11.0 available from USGS at the link above.

Source code for Version 11.0 is available from the USGS at the link above. Code for newer versions is maintained in a GitHub repository at

<https://github.com/respec/FORTRAN/tree/c869a580fc35befc2b702f6420b7a0da05953f2f/lib3.0/SRC>.

User support is provided by AQUA TERRA (now part of RESPEC) at annual HSPF workshops with schedules posted at <http://aquaterra.com/resources/workshops/index.php>. USGS also provides user training on an annual and upon-request basis as detailed at [https://water.usgs.gov/cgi-bin/man\\_wrdapp?hspf#HISTORY](https://water.usgs.gov/cgi-bin/man_wrdapp?hspf#HISTORY).

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## POINT OF CONTACT

U.S. Geological Survey point-of-contact is:

U.S. Geological Survey  
Hydrologic Analysis Software Support Program  
437 National Center  
Reston, VA 20192  
[h2osoft@usgs.gov](mailto:h2osoft@usgs.gov)

The WinHSPF/BASINS point of contact is:

Glenn Fernandez  
U.S. Environmental Protection Agency Region 4  
61 Forsyth Street SW

Atlanta, Georgia 30303

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## COMMUNITY USER PORTAL

BASINS offers an online community where users can exchange questions and answers, including those relevant to HSPF, which can be joined by sending an email to [lyris@lists.epa.gov](mailto:lyris@lists.epa.gov), leaving the "Subject:" field blank and putting "subscribe basinsinfo firstname lastname" in the body of the text.

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## DOCUMENTATION AND TRAINING MATERIALS

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### THEORETICAL DOCUMENTATION

Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jr., Donigan, A.S., Jr., and Johanson, R.C. 1997. Hydrological Simulation Program--FORTRAN, User's Manual for Version 11. EPA/600/R-97/080, prepared for the U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, GA.

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### USER MANUAL

HSPF user's manual (Bicknell et al. 1997) for Version 11.0 is available from the USGS at <https://water.usgs.gov/software/HSPF/> and includes model theory documentation for the included simulation algorithms.

HSPF user's manual (Bicknell et al. 2005) for Version 12.2 is available as part of the BASINS 4.1 download package available at <https://www.epa.gov/exposure-assessment-models/basins-download-and-installation> and includes model theory documentation for the included simulation algorithms.

Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jobes, T.H., and Jr., Donigan, A.S. 2005. HSPF Version 12.2 User's Manual User's. Prepared for the U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, GA.

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## TRAINING MATERIALS

Recommendations for the application of HSPF are contained in the following article:

Duda, P.B., P.R. Hummel, A.S. Donigian, Jr., and J.C. Imhoff. 2012. BASINS/HSPF: Model use, calibration, and validation. *Transactions of the ASABE*, 55(4): 1523-1547.

HSPF tutorials are included as part of the BASINS software distribution and are available at <https://www.epa.gov/exposure-assessment-models/basins-tutorials-and-training>. The BASINS website also contains a series of Technical Notes, many of which focus on different aspects of the construction and calibration of HSPF models. See <https://www.epa.gov/exposure-assessment-models/basins-technical-notes>.

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## EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

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### MODEL APPLICATION PAPERS

Publications of recent HSPF model applications include:

Mishra, A., B.R. Bicknell, P.B. Duda, A.S. Donigian, Jr. and M. H. Gray. (2017). HSPEXP+: An enhanced expert system for HSPF model calibration—A case study of the Snake River Watershed in Minnesota. *Journal of Water Management Modeling*, 25:C422 <https://doi.org/10.14796/JWMM.C422>.

Dudula, J., and T.O. Randhir. (2016). Modeling the influence of climate change on watershed systems: Adaptation through targeted practices. *Journal of Hydrology*, 541(B): 703-713.

Stern, M., L. Flint, J. Minear, A. Flint, and S. Wright. (2016). Characterizing changes in streamflow and sediment supply in the Sacramento River Basin, California, using Hydrological Simulation Program—FORTRAN (HSPF). *Water*, 8(10): 432; doi:10.3390/w8100432.

M.E. Berndt, W. Rutelonis, and C. P. Regan. (2016). A comparison of results from a hydrologic transport model (HSPF) with distributions of sulfate and mercury in a mine-impacted watershed in northeastern Minnesota, *Journal of Environmental Management*, 181: 74-79.

Luo, C., Z. Li, K. Jiang., X. Chen, and H. Li. (2017). Comprehensive study on parameter sensitivity for flow and nutrient modeling in the Hydrological Simulation Program Fortran model. *Environmental Science and Pollution Research*, 24(26): 20982–20994.

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### RECENT PROJECT REPORTS

Michael Baker Jr., Inc., Aqua Terra, Consultants, and Dynamic Solutions, LLC. 2015. Final Setup, Calibration and Validation for Illinois River Watershed Nutrient Model and Tenkiller Ferry Lake EFDC Water Quality Model. Prepared for U. S. Environmental Protection Agency, Region 6, Dallas TX.

Tetra Tech, Inc. 2013. Root River Model Calibration. Prepared for the U.S. Environmental Protection Agency Region 5 and the Minnesota Pollution Control Agency by Tetra Tech, Inc., Research Triangle Park, NC .

U.S. Environmental Protection Agency (EPA). 2010. Chesapeake Bay Total Maximum Daily Load (TMDL) for Nitrogen, Phosphorus and Sediment. U.S. Environmental Protection Agency, Region 3, Chesapeake Bay Program Office, Annapolis, MD.

Tetra Tech, Inc. 2012. Santa Maria Watershed TMDL – Salt Modeling. Prepared for the Central Coast Regional Water Quality Control Board and U.S. Environmental Protection Region 9 by Tetra Tech, Inc., San Diego, CA.

Florida Department of Environmental Protection (FDEP). 2009. Final TMDL Report, Nutrient TMDL for the Caloosahatchee Estuary (WBIDs 3240A, 3240B, 3240C). Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration, South District, Tallahassee, FL.

## LSPC

Loading Simulation Program in C++ is a recoded version of the Hydrologic Simulation Program FORTRAN (HSPF). Like HSPF, LSPC is a comprehensive model for the simulation of watershed hydrology and water quality for both conventional pollutants and toxic chemicals. It enables simulation of both land based runoff, temperature, and pollutant loading with instream hydraulic and pollutant fate and transport processes in 1-dimensional stream channels. Watershed hydrology simulations are based on the Stanford Watershed Model and consist of a water balance method that defines the water storage for surface and soil layers. Water storage is modified by interception, infiltration, evapotranspiration, and losses to inactive groundwater with outflows simulated from surface and subsurface (interflow and groundwater outflow) layers. Sediment is simulated as cohesive (silt and clay) and non-cohesive (sand) fractions with loading based on detachment/scour and transport algorithms. Other pollutant loads can be simulated generally using build-up washoff functions and instream transport and fate processes or using the eutrophication modules that explicitly represent the transformation, interaction, and fate of nutrients, phytoplankton, and gases. LSPC is the Loading Simulation Program in C++, a watershed modeling system that includes a streamlined subset of Hydrologic Simulation Program FORTRAN (HSPF) Version 11.0 algorithms for simulating hydrology, sediment, and general water quality on land as well as a detailed stream transport model. There is no inherent limit on the size of the watershed that can be represented in LSPC and it simulates land and instream processes simultaneously.

## MODEL DEVELOPER/STEWARD

LSPC was developed by Tetra Tech, Inc. with funding from the U.S. Environmental Protection Agency (EPA). The initial public release (Version 1.0) was made available in 2002.

Tetra Tech , maintains and distributes the most recent, currently supported version of the model (Version 5.0).

Jon Ludwig  
Tetra Tech  
Tel: 703-385-6000  
[jon.ludwig@tetrattech.com](mailto:jon.ludwig@tetrattech.com)

## MODEL STATUS

The most current model version is Version 5.0, released in 2015. The model executable, database, and source code are distributed and maintained by Tetra Tech.

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## MODEL CODING LANGUAGE

The underlying algorithms of LSPC are coded in C++.

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## PREVIOUS VERSIONS

Selected versions of LSPC are non-proprietary

## ACCESSIBILITY

The available LSPC model executables include Version 5.0 and Version 4.1. Version 5.0 is available from Jon Ludwig, Tetra Tech, 4, whose contact information is provided above.

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## USER COMMUNITY PORTAL

There is no currently supported user community portal.

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#### POINTS-OF-CONTACT:

Jon Ludwig

Tetra Tech

Tel: 703-385-6000

[jon.ludwig@tetratech.com](mailto:jon.ludwig@tetratech.com)

#### DOCUMENTATION AND TRAINING MATERIALS

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##### MODEL THEORY DOCUMENTATION

The underlying algorithms of LSPC are based on those developed for HSPF Version 11.0. Model theory documentation for the latest peer reviewed version of that model (Version 11.0) is available from the USGS at <https://water.usgs.gov/software/HSPF/>.

The Version 3.1 model user manual (Tetra Tech 2009) is available for download from the Los Angeles County Department of Public works at <http://dpw.lacounty.gov/wmd/wmms/docs/LSPC-UserManual.pdf>.

Tetra Tech. 2009. Loading Simulation Program in C++ (LSPC) Version 3.1 User's Manual. Developed for the County of Los Angeles Department of Public Works Watershed Management Division, Alhambra, CA.

The Version 5.0 model user manual (Tetra Tech 2017) is available upon request from Jon Ludwig.

Tetra Tech. 2017. Loading Simulation Program in C++ (LSPC) Version 5.0 – User's Manual. Developed for the U.S. Environmental Protection Agency and the Montana Department of Environmental Quality under EPA Contract # EP-R8-12-04. December 6, 2017.

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##### RECENT PROJECT APPLICATION REPORTS AND PAPERS

Example applications of LSPC are included in the Version 3.2 model user's manual. Publications of recent LSPC model applications include:

Virginia Department of Environmental Quality (VADEQ). 2016. James River Watershed Model Refinements for Chlorophyll-a Criteria Assessment. Prepared by Tetra Tech, Inc. for the Virginia Department of Environmental Quality, Richmond VA.

Tetra Tech. 2016. Watershed Model Development to Support the San Diego Region Beaches and Creeks Bacteria TMDLs. Prepared for the City of San Diego Storm Water Division by Tetra Tech Inc., San Diego CA.

Tetra Tech. 2014. Lake B. Everett Jordan Watershed Model Report. Prepared for the North Carolina Nutrient Science Advisory Board, North Carolina Division of Water Resources and Triangle J Council of Governments by Tetra Tech, Inc., Research Triangle Park, NC.

Tetra Tech. 2010. Los Angeles County Water Model Configuration and Calibration. Prepared for the County of Los Angeles Department of Public Works by Tetra Tech, Inc., Fairfax, VA.

Tetra Tech. 2009. Final Roanoke River PCB TMDL Development (Virginia). Prepared for the U.S. Environmental Protection Agency, Region 3 by Tetra Tech, Inc., Pasadena, CA.



## QUAL2KW

QUAL2Kw, is a one-dimensional river and stream water quality model that simulates temperature, dissolved oxygen nutrients, pH, periphyton, macrophytes, phytoplankton, and sediment diagenesis. Based on QUAL2K (Chapra and Pelletier 2003), it includes additional processes and options relative to QUAL2K. Both models are modernized version of EPAs QUAL2E model, incorporating more recent science and allowing for application to shallow, upland streams. QUAL2E, QUAL2K, and QUAL2Kw have historically been applied to steady state representation of stream responses with diel variability in boundary conditions. Version 6 of QUAL2Kw now allows continuous simulation with non-steady, non-uniform flow using kinematic wave flow routing. The model framework includes a genetic algorithm to automate the calibration of kinetic parameters and provides capabilities for Monte Carlo simulation investigation of uncertainty and sensitivity. Water quality simulations include nutrient dynamics, algal production, dissolved oxygen with the impact of benthic and carbonaceous demand, pH, and alkalinity.

## MODEL DEVELOPER/STEWARD

### LEAD DEVELOPER(S) AND AFFILIATION

Developed by Greg Pelletier (State of Washington Department of Ecology) and Steve Chapra and Hua Tao (Tufts University).

### MAINTENANCE STATUS AND FUNDING SOURCE

The State of Washington Department of Ecology maintains the model and provides financial resources that support public access to the model, continued updates, and maintenance of updated documentation.

## MODEL STATUS

### CURRENT MODEL VERSION

Version 5.1, July 2008 – for simulating steady flow

Version 6.0, July 2015– for non-steady, non-uniform flow using kinematic wave flow routing

### MODEL CODE LANGUAGE

QUAL2Kw is nonproprietary. It uses Microsoft Excel as the user interface for input, running and viewing output—programmed in Visual Basic for Applications (VBA). The core model is a compiled Fortran 95 program run by the Excel VBA program.

## ACCESSIBILITY

QUAL2Kw is provided by the State of Washington Department of Ecology at:

<http://www.ecy.wa.gov/programs/eap/models.html>

### MODEL EXECUTABLE

The model uses Microsoft Excel as the user interface. The Excel interface calls a compiled dynamic link library to perform numerical calculations, with results returned to the Excel interface.

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## SOURCE CODE

VBA source code is available and unlocked in the Microsoft Excel developer windows. The Fortran source code is not supplied on the Ecology server.

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## USER COMMUNITY PORTAL

[QUAL2K User Group](#)—note this is a user group for QUAL2K not QUAL2Kw but some posts related to QUAL2Kw have been made.

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## ACCESS POINT-OF-CONTACT

Greg Pelletier, Environmental Engineer  
Department of Ecology  
P.O. Box 47600  
Olympia, WA 98504-7600  
360.407.6485  
[Gpei461@ecy.wa.gov](mailto:Gpei461@ecy.wa.gov)

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## DOCUMENTATION AND TRAINING MATERIALS

General information is provided at the following links:

[EPA Science Inventory Fact Sheet](#)

[Washington State Department of Ecology Model Page with overview information for QUAL2Kw](#)

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## MODEL THEORY DOCUMENTATION

Pelletier, Gregory J., S. Chapra, and H. Tao. (2006). [QUAL2Kw - A framework for modeling water quality in streams and rivers using a genetic algorithm for calibration](#). Environmental Modelling and Software, volume 21 pp. 419-425. (2006).

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## USER MANUAL (INCLUDING MODEL VERSION AND PUBLICATION YEAR)

### Version 5.1

QUAL2Kw Theory and Documentation (version 5.1) A modeling framework for simulating river and stream water quality. July 2008. Publication Number 04-03-010. (Available with [model download](#))

### Version 6.0

No documentation accompanies the download with Version 6.0. While this version contains some features that are not in Version 5.1, the 5.1 materials are applicable to Version 6.0.

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## EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

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### PROJECT APPLICATION PAPERS

Butcher, J. B., M. Faizullahoy, H. Nicholas, P. Cada, and J. T. Kennedy. (2016). [Quantitative Assessment of Temperature Sensitivity of the South Fork Nooksack River under Future Climates using QUAL2Kw](#). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/233, 2016.

Cristea, N.C., and S. J. Burges. (2010). An assessment of the current and future thermal regimes of three streams located in the Wenatchee River basin, Washington State: Some implications for regional river basin systems. *Climatic Change*, 102:493–520.

Gikas, G.D. (2014). Water quality of drainage canals and assessment of nutrient loads using QUAL2Kw. *Environmental Processes*, 1(4): 369-385.

Kannel, P.R., S. Lee, Y.-S. Lee, S.R. Kanel, and G.J. Pelletier (2007). Application of automated QUAL2Kw for water quality modeling and management in the Bagmati River, Nepal. *Ecological Modeling*, 202: 503-517.

Sharma, D., A. Kansal, and G. Pelletier (2017). Water quality modeling for urban reach of Yamuna River, India (1999–2009), using QUAL2Kw. *Applied Water Science*, 7(3): 1535-1559.

Turner, D.F., G.J. Pelletier, and B. Kasper. (2009). Dissolved oxygen and pH modeling of a periphyton dominated, nutrient enriched river. *Journal of Environmental Engineering*, 135(8): 645-652.

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#### TMDLS

North Fork Palouse River TMDL (<https://fortress.wa.gov/ecy/publications/SummaryPages/1510029.html>)

Wenatchee River TMDL (<https://fortress.wa.gov/ecy/publications/summarypages/0810062.html>)

Bear-Evans Watershed TMDL (<https://fortress.wa.gov/ecy/publications/SummaryPages/0810058.html>)

#### Jordan River TMDL

([https://deg.utah.gov/ProgramsServices/programs/water/watersheds/docs/2013/09Sep/JordanRiverTMDL\\_Final\\_20130905.pdf](https://deg.utah.gov/ProgramsServices/programs/water/watersheds/docs/2013/09Sep/JordanRiverTMDL_Final_20130905.pdf))

Umpqua Basin TMDL (<http://www.oregon.gov/deg/wq/tmdls/Pages/TMDLs-Umpqua-Basin.aspx>) Appendix 3 of the Umpqua Basin TMDL describes the model application

(<http://www.oregon.gov/deg/FilterDocs/umpappx3nut.pdf>)

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#### TRAINING MATERIALS

EPA Modeling Workgroup Water Quality Modeling Webinar #4: [Nooksack River QUAL2Kw Temperature Model and Climate Change Scenarios](#).

The model co-developer, Greg Pelletier, may [offer training on QUAL2Kw](#).

## SPARROW

The SPAtially Referenced Regressions On Watershed attributes (SPARROW) model applies statistical methods to relate measured water quality with local landscape characteristics. The model uses a multi-variable regression equation to relate instream water quality measurements to those characteristics, including land use, point sources, soil type, precipitation, and other environmental measures. The model also explicitly considers factors that affect the timing and delivery of pollutants. This statistical approach to non-conservative transport allows the model to estimate loads in ungaged basins, assuming that the explanatory datasets are available to characterize the area under examination. Empirical estimates of relative source contributions are also included. In general, model output is used to describe water quality loading and concentration conditions representative of long-term averages.

## MODEL DEVELOPER/STEWARD

SPARROW was developed by the United States Geological Survey (USGS). Richard Smith, Gregory Schwarz, and Richard Alexander are the original developers of SPARROW. The national and regional SPARROW contacts are summarized in Table 0.

Table 10. National and regional SPARROW contacts

Person of Contact	National or Regional Level	Contact Information
Richard Alexander	National	703-648-6869 (ralex@usgs.gov)
Steve Preston	National	410-267-9875 (spreston@usgs.gov)
Gregory Schwarz	National	703-648-5718 (gschwarz@usgs.gov)
Richard Smith	National	703-648-6870 (rsmith1@usgs.gov)
Richard Moore	Regional – New England and Mid-Atlantic	603-226-7825 (rmoore@usgs.gov)
Anne Hoos	Regional - South Atlantic-Gulf and Tennessee	615-837-4760 (abhoos@usgs.gov)
Dale Robertson	Regional -Great Lakes, Ohio, Upper Mississippi, and Souris-Red-Rainy	608-821-3867 (dzrobert@usgs.gov)
Juliane Brown	Regional -Missouri	303-236-6876 (jbbrown@usgs.gov)
Richard Rebich	Regional -Lower Mississippi, Arkansas-White-Red, Texas-Gulf	601-933-2928 (rarebich@usgs.gov)
David Anning	Regional - Rio Grande, Colorado, and Great Basin	928-556-7139 (dwanning@usgs.gov)
Daniel Wise	Regional - Pacific Northwest	503-251-3213 (dawise@usgs.gov)
John Brakebill	Regional - Chesapeake Bay	410-238-4257 (jwbrakeb@usgs.gov)

### Maintenance status:

The USGS is in the process of developing an R based version of SPARROW, and should be available in late 2018. Also, they are developing a web-based mapping system to illustrate and explore SPARROW model results, a beta version of the web portal is available (<http://wim.usgs.gov/sparrowmrb3/sparrowmrb3mapper.html#>.)

SPARROW decision support system (DSS) is no longer available as of July 31, 2017. Contact Steve Preston ([spreston@usgs.gov](mailto:spreston@usgs.gov)) with questions. The site provided access to all publicly available calibrated SPARROW models and would allow the users to display scenario results.

### Funding source:

SPARROW is maintained by USGS National Water-Quality Assessment (NAWQA) to address the changing water quality in response to human and natural factors. The current cycle for NAWQA is planned to run through 2022.

## MODEL STATUS

The version history of SPARROW is summarized in 11.

Table 1. Version History

Version	Release Date	Proprietary or Non-proprietary	Available for Download
Version 1.0	12/1997	Non-proprietary	No
Version 2.1	04/2006	Non-proprietary	No
Version 2.6	8/2006	Non-proprietary	Yes
Version 2.7	12/2006	Non-proprietary	Yes
Version 2.8	6/2007	Non-proprietary	Yes
Version 2.9	10/2007	Non-proprietary	Yes

System requirements include: SAS version 8.0 (or higher), Windows 95 or Windows NT Version 4.0 (or higher), 64 megabytes of memory, and minimum hardware configuration of Intel or Intel-compatible Pentium class processor. The model execution requires the following SAS components: Base SAS, the SAS statistical procedure (SAS/STAT) and SAS/IML. The SAS Geographic Information System (SAS/GIS) component is optional.

## MODEL CODE

The SPARROW model code is written in SAS macro language, with statistical procedures written in the SAS IML. The source code is available within the download package. The control files for specific models would only be available from the model developers.

## ACCESSIBILITY

### EXECUTABLE AND SOURCE CODE

Model executable and source code is downloadable from USGS, see Table 12.

Table 12. Model executables

Version	Link	Source Code Available
Version 2.6	<a href="#">Download Version 2.6</a>	Yes
Version 2.7	<a href="#">Download Version 2.7</a>	Yes
Version 2.8	<a href="#">Download Version 2.8</a>	Yes
Version 2.9	<a href="#">Download Version 2.9</a>	Yes
Optional GIS Files	<a href="#">Download GIS Files</a>	N/A

## USER COMMUNITY PORTAL

There is no user community portal.

## DOCUMENTATION AND TRAINING MATERIALS

### User Manuals

A user manual and journal article represent the theoretical documentation for SPARROW.

- [Regional interpretation of water-quality monitoring data \(1997\)](#)
- [The SPARROW Surface Water- Quality Model: Theory, Application and User Documentation \(2006\)](#)

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#### Recent Applications/Reports

- [A Regional Modeling Framework of Phosphorus Sources and Transport in Streams of the Southeastern United States \(2011\)](#)
- [Calibration and Uncertainty Analysis Using the Sparrow Model for Dissolved-Solids Transport in the Upper Colorado River Basin \(2015\)](#)
- [Enhanced and updated spatially referenced statistical assessment of dissolved-solids load sources and transport in streams of the Upper Colorado River Basin \(2017\)](#)
- [SPARROW Modeling of Nitrogen Sources and Transport in Rivers and Streams of California and Adjacent States, U.S. \(2015\)](#)
- [Source and Delivery of Nutrients to Receiving Waters in the Northeastern and Mid-Atlantic Regions of the United States \(2011\)](#)

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#### TRAINING MATERIALS

No training materials available.

## SWAT

The objective of the Soil and Water Assessment Tool (SWAT) model is to predict the effect of management decisions on water, sediment, nutrient and pesticide yields with reasonable accuracy in moderate to large scale watersheds. SWAT is widely used in assessing soil erosion prevention and control, nonpoint source pollution control and regional management in watersheds, especially agricultural watersheds. SWAT incorporates the EPIC plant growth model. Runoff is generally simulated using a modified Curve Number approach, although Green-Ampt infiltration can also be used, while sediment yield is based on the Modified Universal Soil Loss Equation (MUSLE). Instream simulation uses a daily time step.

## MODEL DEVELOPER/STEWARD

The Soil and Water Assessment Tool (SWAT) is a watershed model jointly developed and maintained by the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) and Texas A&M AgriLife Research, which is part of The Texas A&M University System.

## MODEL STATUS

The current model version is SWAT2012 rev. 664, released in December 2016.

## CODE LANGUAGE

The model code language is FORTRAN (including sections in both FORTRAN 77 and FORTRAN 90 styles).

SWAT undergoes frequent revisions. The major version history of the SWAT model is provided in Table 13, which includes all versions currently available for download. SWAT99.2 and SWAT98.1 are no longer available for download. For information about these earlier versions, contact Jeff Arnold ([jeff.arnold@ars.usda.gov](mailto:jeff.arnold@ars.usda.gov)) or Nancy Sammons ([nancy.sammons@ars.usda.gov](mailto:nancy.sammons@ars.usda.gov)).

Table 13. Model versions for SWAT

Version	Release Date	Proprietary/ Non-Proprietary
SWAT2000	2000	Non-Proprietary
SWAT2005	2005	Non-Proprietary
SWAT2009	2009	Non-Proprietary
SWAT2012	2012	Non-Proprietary
SWAT2012 rev. 664	2016	Non-Proprietary

## ACCESSIBILITY

The model executable for SWAT2012, SWAT2009, SWAT2005 and SWAT 2000 can be freely downloaded from <http://swat.tamu.edu/software/swat-executables/>.

## SOURCE CODE

The source code for each of these versions is also available for download at the same site.

In addition to the SWAT executables, there are also several SWAT extensions and supplementary programs available for download:

- ArcSWAT is an ArcGIS-ArcView extension and graphical user input interface for SWAT and is available for <http://swat.tamu.edu/software/arcswat/>

- QSWAT is an interface for SWAT using the open source QGIS geographic information system software and is available for download at <http://swat.tamu.edu/software/qswat/>.
- SWAT-CUP is a calibration/uncertainty or sensitivity program interface for SWAT and can be downloaded at <http://swat.tamu.edu/software/swat-cup/>.
- SWAT-MODFLOW is an integrated hydrological model that couples SWAT land surface processes with spatially-explicit groundwater flow processes and can be downloaded at <http://swat.tamu.edu/software/swat-modflow/>.
- VIZSWAT is a visualization and analysis tool developed by Baird & Associates for SWAT model output. VIZSWAT analyzes results from SWAT 2000, SWAT 2005, and SWAT 2009 versions as well as AVSWAT and ArcSWAT (ArcGIS-SWAT). VIZSWAT can be purchased and downloaded from <http://swat.tamu.edu/software/vizswat/>.
- MWSWAT is an interface to SWAT using the open source MapWindow geographic information system. MWSWAT can be downloaded at <http://swat.tamu.edu/software/mwswat/>.
- SWAT Check reads model output from a SWAT project and performs a variety of parameter range and mass balance checks to identify potential model problems. SWAT Check can be downloaded at <http://swat.tamu.edu/software/swat-check/>.
- The Soil-Landscape Estimation and Evaluation Program (SLEEP) helps users generate a spatially interpolated soil property database (required as an input to SWAT). It is particularly useful for applications outside the U.S. where spatial soils databases are not readily available and can be downloaded at <http://swat.tamu.edu/software/sleep/>.
- SWAT Bflow is a baseflow filter program that offers a Web Interface to determine runoff/baseflow fraction in streamflow and the baseflow alpha factor required in SWAT .gw files. SWAT Bflow can be downloaded at <http://swat.tamu.edu/software/baseflow-filter-program/>.
- The potential heat unit program estimates the number of heat units required to bring a plant to maturity. This information must be entered in the SWAT management input file for each plant simulated in an HRU. The potential heat unit program can be downloaded at <http://swat.tamu.edu/software/potential-heat-unit-program/>.

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#### USER COMMUNITY PORTAL

Multiple SWAT User Groups (found at <http://swat.tamu.edu/support/>) enable users to exchange ideas and questions about the use of the SWAT model as well as the many SWAT extensions or accessories. The SWAT development team monitors all messages posted to the user groups. There are user groups for SWAT, ArcSWAT, VizSWAT, SWAT-CUP, QSWAT and SWAT MODFLOW. There are also international SWAT groups for users in Latin America, Southeast Asia, Africa, Iran and Brazil.

#### DOCUMENTATION AND TRAINING MATERIALS

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##### MODEL THEORY DOCUMENTATION

All documentation for the SWAT model can be found at [swat.tamu.edu/documentation/](http://swat.tamu.edu/documentation/). The documentation includes *Soil and Water Assessment Tool Theoretical Documentation* for SWAT versions 2000, 2005 and 2009 (Neitsch et al. 2002, 2005 and 2011). There is also *Input/Output File Documentation* for SWAT versions 2005, 2009 and 2012 (Neitsch et al. 2004 and 2011; Arnold et al. 2012).



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## USER MANUAL

The current version of the user's manual, (Arnold et al. 2012) as well as older versions can be found at [swat.tamu.edu/documentation/](http://swat.tamu.edu/documentation/).

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## EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

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### RECENT PAPERS

Bai, J., Z. Shen, T. Yan, J. Qui and Y. Li. (2017). Predicting fecal coliform using the interval-to-interval approach and SWAT in the Miyun watershed, China. *Environmental Science and Pollution Research*. 24(18): 15462–15470.

Carvalho-Santos, C., A.T. Monteiro, J.C. Azevedo, J.P. Honrado and J.P. Nunes. (2017). Climate change impacts on water resources and reservoir management: Uncertainty and adaption for a mountain catchment in northeast Portugal. *Water Resources Management*. 31(11): 3355–3370.

Jung, C.G. and S.J. Kim. (2017). SWAT modeling of nitrogen dynamics considering atmospheric deposition and nitrogen fixation in a watershed scale. *Agricultural Sciences*. 8: 326-340.

Kundu, S., D. Khare and A. Mondal. (2017). Past, present and future land use changes and their impact on water balance. *Journal of Environmental Management*. 197: 585-596.

Thodsen, H., C. Farkas, J. Chormanski, D. Trolle, G. Blicher-Mathiesen, R. Grant, A. Engebretsen, I. Kardel and H.E. Andersen. (2017). Modeling nutrient load changes from fertilizer application scenarios in six catchments around the Baltic Sea. *Agriculture*. 7(5):41.

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### OTHER IMPORTANT PAPERS

Arnold, J.G., D. N. Moriasi, P. W. Gassman, K. C. Abbaspour, M. J. White, R. Srinivasan, C. Santhi, R. D. Harmel, A. van Griensven, M. W. Van Liew, N. Kannan, M. K. Jha. (2012). SWAT: Model Use, Calibration, and Validation. *Transactions of the ASABE*. 55(4): 1491-1508.

Douglas-Mankin, K.R., Srinivasan, R. and Arnold, J.G., (2010). Soil and Water Assessment Tool (SWAT) model: Current developments and applications. *Transactions of the ASABE*. 53(5):1423-1431.

Gassman, P.W., M. R. Reyes, C. H. Green, and J. G. Arnold. (2007). The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions. *Transactions of the ASABE*. 50(4): 1211-1250.

Gassman, P.W., Sadeghi, A.M. and Srinivasan, R., (2014). Applications of the SWAT model special section: overview and insights. *Journal of Environmental Quality*. 43(1):1-8.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, J.R. Williams, 2011. Soil and Water Assessment Tool Theoretical Documentation Version 2009. Texas Water Resources Institute Technical Report No. 406, Texas A&M University System, College Station, Texas.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, R. Srinivasan, J.R. Williams. 2002. Soil and Water Assessment Tool User's Manual Version 2000. Texas Water Resources Institute Technical Report No. TR-192, Texas A&M University System, College Station, Texas.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, R. Srinivasan, J.R. Williams. 2004. Soil and Water Assessment Tool Input/Output File Documentation Version 2005. USDA-ARS Temple, Texas.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, R. Srinivasan, J.R. Williams. 2005. Soil and Water Assessment Tool Theoretical Documentation Version 2005. USDA-ARS Temple, Texas.

Pfannerstill, M., K. Bieger, B. Guse, D. D. Bosch, N. Fohrer and Jeffrey G. Arnold. (2017). How to Constrain Multi-Objective Calibrations of the SWAT Model Using Water Balance Components. *Journal of the American Water Resources Association (JAWRA)*. 53(3):532-546.

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#### TRAINING MATERIALS

The Grassland, Soil and Water Research Laboratory and Blackland Research Center in Texas cosponsor workshops periodically. The SWAT development team also collaborates with other agencies/firms to set up workshops outside of Texas. The site [swat.tamu.edu/workshops/](http://swat.tamu.edu/workshops/) provides summaries of the different types of workshops provided and a list of upcoming events. In addition to the workshops, there are also training videos available that enable online instruction for SWAT users (see [swat.tamu.edu/workshops/instructional-videos/](http://swat.tamu.edu/workshops/instructional-videos/)).

## SWMM

The Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for continuous simulation of runoff quantity and quality from primarily urban and suburban watersheds. The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps. SWMM flow simulations include fully dynamic flow routing that allows for backwater, surcharging, pressurized flow, and looped connections. SWMM is also capable of simulating a variety of Low Impact Development (LID) practices (such as bio-retention cells, permeable pavement, and green roofs) as well as more traditional storage-based BMPs (such as detention ponds). It has been widely applied for more than 40 years for the assessment of urban stormwater systems, including combined storm sewers. SWMM is the engine for EPA's National Stormwater Calculator software.

## MODEL DEVELOPER/STEWARD

SWMM was first released in 1971 with funding from the Water Quality Office of the U.S. Environmental Protection Agency (EPA) with development led by Metcalf & Eddy, Inc., the University of Florida, and Water Resources Engineers, Inc. During the 1980's and 90's the model was periodically updated by the University of Florida, Oregon State University and CDM-Smith with funding and oversight provided by the EPA Research Lab, Athens, GA. In 2002 a CRADA was established between the EPA National Risk Management Research Laboratory (NRMRL) and CDM-Smith to re-write the entire SWMM computational model in object-based C and provide it with a modern graphical user interface. The result of this effort, SWMM 5, was released in 2005. NRMRL has continued to develop SWMM in-house, by adding new features such as LID modeling and making numerous other improvements.

The current version of SWMM, release 5.1.012, is maintained by EPA NRMRL.

## MODEL STATUS

The current version of SWMM (5.1.013) was released in 2018.

## MODEL LANGUAGE

The SWMM computational engine is coded in C and exists as both a dynamic link library (DLL) and a stand-alone command line executable. SWMM's graphical user interface is written in Delphi-Pascal for the Windows operating system and is used in conjunction with the engine's DLL to run a simulation.

EPA's version of SWMM is non-proprietary, open source, and public domain.

In addition to non-proprietary versions of SWMM, there are numerous examples of developers layering custom "wrappers" onto the SWMM algorithms to streamline the model setup for users, as well as provide enhanced functionality, as well as management and visualization tools. Two of the most used of these non-proprietary versions include PCSWMM developed by Computational Hydraulics International (CHI) and XPSWMM developed by XP solutions. Information for these model versions can be accessed from their respective websites at:

<https://www.pcswmm.com/>

<http://xpsolutions.com/software/xpswmm/>

## ACCESSIBILITY

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## EXECUTABLE AND SOURCE CODE

The SWMM Model Version 5.1.012 executable and source code is available at <https://www.epa.gov/water-research/storm-water-management-model-swmm#downloads>. The executable and source code for other 5.1.X versions, as well as Versions 4.4, 4.31, and 4.3 are available from <https://www.pcswmm.com/Downloads/USEPASWMM>.

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## USER COMMUNITY PORTAL

CHI maintains an OpenSWMM website that provides free access to a large knowledge base of SWMM information as well as a list server that allows users to exchange information and questions. More information can be found at: <https://www.openswmm.org/Forum/About#swmm-userslistserver>.

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## POINT OF CONTACT

The EPA NRMRL point of contact for SWMM is:

[simon.michelle@epa.gov](mailto:simon.michelle@epa.gov)

US EPA Research

National Risk Management Research Laboratory

Mail Code: 689

26 W. Martin Luther King Blvd.

Cincinnati, OH 45268

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## DOCUMENTATION AND TRAINING MATERIALS

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### MODEL THEORY DOCUMENTATION AND USER MANUAL

Model theory documentation, as well as the User's manual (Rossman 2015) for the latest Version 5.1.012 is available for download from <https://www.epa.gov/water-research/storm-water-management-model-swmm#documents>.

Rossman, L. A. 2015. *Storm Water Management Model User's Manual Version 5.1*. National Risk Management Laboratory of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. EPA/600/R-14/413b

Rossman, L. A. and Huber, W.C. 2016a. *Storm Water Management Model Reference Manual Volume I – Hydrology*. National Risk Management Laboratory of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. EPA/600/R-15/162A

Rossman, L. A. and Huber, W.C. 2016b. *Storm Water Management Model Reference Manual Volume III - Water Quality*. National Risk Management Laboratory of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. EPA/600/R-16/093

Rossman, L. A. 2017. *Storm Water Management Model Reference Manual Volume II – Hydraulics*. National Risk Management Laboratory of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. EPA/600/R-17/111

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## EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

Example SWMM applications are included in the Storm Water Management Model Applications Manual (Gironas et. Al. 2009) available for download from <https://www.epa.gov/water-research/storm-water-management-model-swmm#documents>. Publications of recent SWMM model applications include:

Niazi, M., C. Nietch, Mahdi Maghrebi, N. Jackson; B. R. Bennett, M. Tryby; and A. Massoudieh (2017). "Storm Water Management Model: Performance Review and Gap Analysis." *Journal of Sustainable Water in the Built Environment*, 3(2).

Philadelphia Water Department. (2013). Tributary Water Quality Model for Bacteria, Consent Order & Agreement Deliverable VI, City of Philadelphia Combined Sewer Overflow Long Term Control Plan Update. Submitted to the Commonwealth of Pennsylvania Department of Environmental Protection by the Philadelphia Water Department, Philadelphia, PA.

City of North Miami. (2012). Stormwater Master Plan Update, Final Report. Prepared by CDM Smith for the City of North Miami, Miami, FL.

Fairfax County Department of Public Works and Environmental Services. (2010). Pohick Creek Watershed Management Plan. Fairfax County Department of Public Works and Environmental Services - Stormwater Planning Division, Fairfax, VA.

Gironas, J., Roesner, L. A., and Davis, J. (2009). *Storm Water Management Model Applications Manual*. EPA/600/R-09/077, National Risk Management Laboratory of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH.

Fairfax County Department of Public Works and Environmental Services. (2007). Cameron Run Watershed Management Plan. Fairfax County Department of Public Works and Environmental Services - Stormwater Planning Division, Fairfax, VA.

D.C. Department of Health (DDOH). (2004). Final Total Maximum Daily Load for Metals in Rock Creek. D.C. Department of Health Environmental, Health Administration, Bureau of Environmental Quality, Water Quality Division, Washington, DC.

## SWTOOLBOX

The Surface Water Toolbox (SWToolbox) combines EPA's DFLOW program and USGS' SWSTAT tool into a single tool designed to facilitate easy import of USGS NWIS streamflow data and user-defined text files. SWToolbox contains a set of procedures for statistical analysis of time-series data to support water-quantity and water-quality modeling. It is primarily geared toward conducting n-day frequency computations (e.g., 7Q-10 flows) as well as computing biologically critical flows. SWToolbox can specifically perform flow-duration analysis; compute an n-day high or low annual time series; perform frequency analysis using the log-Pearson Type III distribution; perform Kendall Tau analysis for trend; and compute duration hydrograph tables and curves.

## MODEL DEVELOPER/STEWARD

The SWToolbox was developed in partnership with U.S. Geological Survey (USGS) and U.S. Environmental Protection Agency (EPA) with technical support provided by RESPEC.

## MODEL STATUS

SWToolbox was publicly released in early 2018. The Watershed Academy is hosting a webcast for the Surface Water Toolbox on February 8<sup>th</sup>, 2018.

## ACCESSIBILITY

The tool can be downloaded from <https://water.usgs.gov/osw/swtoolbox/>.

The software is a windows desktop application that is built on the BASINS system. The tool is built on the open-source MapWindow GIS software.

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### User Community Portals

No community portals.

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### Access Points of Contact

There are multiple points of contact, as listed in Table 14.

Table 4. Points of Contact

Contact	Agency/Company	Email Address
Help Desk	USGS	<a href="mailto:SWToolboxTesting@usgs.gov">SWToolboxTesting@usgs.gov</a>
Julie Kiang	USGS	<a href="mailto:JKIANG@USGS.GOV">JKIANG@USGS.GOV</a>
Brian Nickel	USEPA	<a href="mailto:nickel.brian@epa.gov">nickel.brian@epa.gov</a>
Jenny Molloy	USEPA	<a href="mailto:molloy.jennifer@epa.gov">molloy.jennifer@epa.gov</a>
Paul Hummel	RESPEC	<a href="mailto:Tong.zhai@respec.com">Tong.zhai@respec.com</a>

## DOCUMENTATION AND TRAINING MATERIALS

There is a [draft user manual](#) and a [demonstration](#) available on the SWToolbox [website](#).

## VISUAL PLUMES

Visual Plumes is a Windows-based computer application that estimates dilution of outfall discharges. Visual Plumes supersedes the DOS PLUMES (Baumgartner, Frick, and Roberts 1994) mixing zone modeling system. Visual Plumes is used for simulating plumes in all waterbody types. It assists in the preparation of mixing zone analyses for NPDES permits. Visual Plumes simulates single and merging submerged plumes in arbitrarily stratified ambient flow and buoyant surface discharges. A limitation with this model is that it does not simulate interaction of the plume with boundaries (e.g., shorelines).

Visual Plumes incorporates a suite of models including: DKHW model that is based on UDKHDEN (Muellenhoff et al. 1985), the surface discharge model PDS (Davis 1999), the three-dimensional UM3 model based on UM, and the NRFIELD model based on RSB. These models can be run consecutively and compared graphically to help assess performance and uncertainty.

## MODEL DEVELOPER/STEWARD

Visual Plumes was developed by the U.S. Environmental Protection Agency's (EPA) Center for Exposure Assessment Modeling (CEAM) and is a Windows-based model that replaces DOS PLUMES developed by Baumgartner, Frick and Roberts in 1994. Various entities have contributed in the development of the modeling system, namely the National Exposure Research Laboratory (NERL) of the U.S. EPA in Athens, Georgia; CH2M HILL in Corvallis, Oregon; Brown and Caldwell in Atlanta, Georgia, University of Arizona in Tucson, Arizona and Alaska Department of Environmental Conservation in Juneau, Alaska.

## MODEL STATUS

According to EPA CEAM's Visual Plumes website, the current Visual Plumes model version is 1.0 and was released August 2001. However, correspondence with EPA CEAM staff indicates that Visual Plumes 2009 is the latest version. The model is non-proprietary and is updated periodically. The update file, UPDATE\_VPLUME.EXE, is available for download at <https://www.epa.gov/exposure-assessment-models/visual-plumes> or the most recent model version can be requested by submitting a request to EPA at <https://www.epa.gov/exposure-assessment-models/forms/center-exposure-assessment-models-contact-us>.

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## MODEL CODE

The model code language is Visual Basic. Visual Plumes runs on Windows 95/98/NT/2000/ and XP. There is no Windows 7 or later compatible version and no plans to upgrade to 64bit. Some clients have had success installing Virtual Box running Windows XP, then install Visual Plumes on the Virtual Box.

There is no model code of previous versions of Visual Plumes available. A 2005 draft model update document is available on the internet that identifies and describes key updates that were made to the modeling system ([https://clu-in.org/conf/tio/r10mixingzone\\_012213/2005-MZcourse-draft.pdf](https://clu-in.org/conf/tio/r10mixingzone_012213/2005-MZcourse-draft.pdf)). Since the release of Visual Plumes version 1.0 in 2001, numerous changes have been made to the application to improve its performance and post-2001 compilations of the software have been made available to users on request; however, the web version available at the EPA website has remained unchanged. Major changes to the Visual Plumes modeling system include:

- Contouring
- Far-field progressive vector diagram (PVD) plume tracking
- Improvements to the PDS surface discharge model (and other models)
- Plume morphology in small streams beyond the fully-mixed region
- Arbitrary source location

## ACCESSIBILITY

The U.S. EPA Visual Plumes model can be downloaded and installed from the U.S. EPA CEAM web site (<https://www.epa.gov/exposure-assessment-models/visual-plumes>).

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## SOURCE CODE

The FORTRAN source code for the various models (only model executables) in the modeling system is not supplied at the U.S. EPA CEAM website.

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## CONTACT:

The author of Visual Plumes, Dr. Walter Frick, retired from EPA with no support successor.

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## USER COMMUNITY PORTAL

There is no user community portal.

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## DOCUMENTATION AND TRAINING MATERIALS

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### MODEL THEORY DOCUMENTATION

The Visual Plumes model theory is presented in section 7 of the Visual Plumes Guidance Manual (Frick et al. 2003). <https://www.epa.gov/sites/production/files/documents/VP-Manual.pdf>

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### USER MANUAL

The user's manual can be downloaded at <https://www.epa.gov/exposure-assessment-models/dilution-models-effluent-discharges-visual-plumes-4th-edition>. The manual is titled *Dilution Models for Effluent Discharges 4th Edition (Visual Plumes)* (Frick et al. 2003).

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### EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

Baumgartner, D., W. Frick, P. Roberts. (1994). *Dilution Models for Effluent Discharges (3rd Ed)*. EPA/600/R-94/086, U.S. Environmental Protection Agency, Pacific Ecosystems Branch. Newport, Oregon.

Davis, L.R. (1999). *Fundamentals of Environmental Discharge Modeling*. CRC Press. Boca Raton, FL.

Frick, W.E. (2004). Visual Plumes Mixing Zone Modeling Software. *Environmental Modelling &*

Frick, W., A. Ahmed, K. George, A. Laputz, G. Pelletier and P. Roberts. (2010). On Visual Plumes and associated applications.

Muellerhoff, W.P., A.M. Soldate, Jr., D.J. Baumgartner, M.D. Schuldt, L.R. Davis, and W.E. Frick, (1985). *Initial mixing characteristics of municipal ocean outfall discharges: Volume 1*. Procedures and Applications. EPA/600/3-85/073a. Environmental research Laboratory, U.S. Environmental Protection Agency. Narragansett, RI.

Palomar, P., Lara, J. L., & Losada, I. J. (2012). Near field brine discharge modeling part 2: Validation of commercial tools. *Desalination*. 290:28–42.

Palomar, P., Lara, J. L., Losada, I. J., Rodrigo, M., & Alvarez, A. (2012). Near field brine discharge modelling part 1: Analysis of commercial tools. *Desalination*. 290:14–27.



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#### TRAINING MATERIALS

Once the Visual Plumes installation package is installed, instructional material can be found in the folder entitled "Mixing zone course units". The materials are based on the California State Water Resources Control Board mixing zone course (February 2000, presented by Walter Frick and Debra Denton) and subsequent similar courses. These materials are intended as classroom visual aids; however, they can also be used as training for individual users.

## WASP

The Water Quality Analysis Simulation Program (WASP8) is a dynamic compartment (or segment)-modeling program for aquatic systems, including both the water column and the underlying benthos. WASP can be linked to free surface hydrodynamic models (e.g., EFDC) to allow the user to investigate water quality dynamics in 1, 2, and 3 dimensional systems (streams, rivers, lakes and estuaries). The hydrodynamic models provide WASP information related to flows, depths, velocities, temperature and salinity. The constituents that can be modeled by WASP include conventional water quality variables (nitrogen, phosphorus, dissolved oxygen, biological oxygen demand, sediment oxygen demand, algae and periphyton), organic chemicals, metals, mercury, pathogens and temperature. WASP can also be linked with watershed models, which allows for multi-year analysis under varying meteorological and environmental conditions.

## MODEL DEVELOPER/STEWARD

The WASP model was first developed in 1981 by Dominic Di Toro, James Fitzpatrick and Robert Thomann of Hydrosience, Inc., now HydroQual, Inc.

Current funding and maintenance of the WASP model is provided by the U.S. Environmental Protection Agency's (EPA) Center for Exposure Assessment Modeling (CEAM). Tim Wool at EPA Region 4 maintains the latest version of WASP ([tim@twool.com](mailto:tim@twool.com)).

## MODEL STATUS

The current model version is WASP 8.1, released in July 2017.

The model code language is FORTRAN and the model interface is in C++.

Previous versions of WASP include WASP7.52, 6, 5.1, 5 and 4. WASP6 was the first version with a windows interface; however, the source code is no longer available. The WASP versions still available for download are presented in Table 15.

Table 15. Model versions for WASP

Version	Release Date	Proprietary/ Non-Proprietary
WASP 8.1	July 2017	Non-proprietary
WASP 8.0	August 2016	Non-proprietary

## ACCESSIBILITY

WASP 8.1 can be downloaded from <http://epawasp.twool.com/installers/>. There is a 64 Bit Windows Installer, 64 Bit Mac OS X (Yosemite or Higher) and 64 Bit Linux (Built on Ubuntu) installer. WASP 7.52 can be downloaded at <https://www.epa.gov/exposure-assessment-models/water-quality-analysis-simulation-program-wasp#model>.

## SOURCE CODE

The source code for WASP 8.1 is available from Tim Wool of EPA Region 4 upon request.

## USER COMMUNITY PORTAL

There is a Google Email Group to support the WASP user community. The group can be found at <https://groups.google.com/d/forum/epawasp>.

## DOCUMENTATION AND TRAINING MATERIALS

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### MODEL THEORY DOCUMENTATION AND USER MANUAL

The WASP user's manual is available by download with the WASP model at <http://epawasp.twool.com/installers/>. The most recent user's manual is:

Wool, Tim A., Robert B. Ambrose, James L. Martin, Edward A. Comer. (2006). *Water quality analysis simulation program (WASP)*. User's Manual, Version 6.

In addition to the main user's manual, there are also eight model theory and user's guide documents that are intended as supplements to the WASP manual. The eight supplemental documents can be downloaded at <http://epawasp.twool.com/docs/> and are listed below.

Ambrose, R.B. and T. Wool. (2017). *WASP8 Stream Transport - Model Theory and User's Guide*. U.S. Environmental Protection Agency Office of Research and Development. Washington, DC.

Authors Unknown. (2017). *The Solids Module – Draft*.

Wool, T.A., R.B. Ambrose, J.L. Martin. (2017). *WASP8 Multiple Algae - Model Theory and User's Guide*. U.S. Environmental Protection Agency Office of Research and Development Washington, DC.

Martin, J.L., R.B. Ambrose and T.A. Wool. (2017). *WASP8 Macro Algae - Model Theory and User's Guide*. U.S. Environmental Protection Agency Office of Research and Development Washington, DC.

Martin, J.L. and T.A. Wool. (2017). *WASP Sediment Diagenesis Routines: Model Theory and User's Guide*. U.S. Environmental Protection Agency Office of Research and Development Washington, DC.

Wool, T.A., R.B. Ambrose, J.L. Martin. (2008). *WASP8 Temperature Model Theory and User's Guide*. U.S. Environmental Protection Agency Office of Research and Development Washington, DC.

Author and date unknown. *pH and Alkalinity*. U.S. Environmental Protection Agency Office of Research and Development Washington, DC.

Authors Unknown. (2017). *The Light Module – Draft*.

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### EXAMPLE PUBLICATIONS OF MODEL APPLICATIONS

Bouchard, D. C. Knightes, X. Chang and B. Avant. (2017). Simulating Multiwalled Carbon Nanotube Transport in Surface Water Systems Using the Water Quality Analysis Simulation Program (WASP). *Environmental Science and Technology*.

Camacho, R. A., J. L. Martin, B. Watson, M. J. Paul, L. Zheng and J. B. Stribling. (2014). Modeling the factors controlling phytoplankton in the St. Louis Bay Estuary, Mississippi and evaluating estuarine responses to nutrient load modifications. *Journal of Environmental Engineering*. 141(3).

Hosseini, N., K. Pan Chun and K. Lindenschmidt. (2016). Quantifying Spatial Changes in the Structure of Water Quality Constituents in a Large Prairie River within Two Frameworks of a Water Quality Model. *Water*. 8(158).

James, R. T. (2016). Recalibration of the Lake Okeechobee Water Quality Model (LOWQM) to extreme hydro-meteorological events. *Ecological Modelling*. 325:71-83.

Lee, I., H. Hwang, J. Lee, N. Yu, J. Yun and H. Kim. (2017). Modeling approach to evaluation of environmental impacts on river water quality: A case study with Galing River, Kuantan, Pahang, Malaysia. *Ecological Modelling*. 353:167-173.

## TRAINING MATERIALS

Information on WASP workshops and registration for workshops can be found at <http://epawasp.twopl.com/>. Multiple video tutorials can be found at <http://epawasp.twopl.com/tutorials/>. The tutorials are meant to help the user understand and apply the model and its associated tools.

A two-hour "Introduction to WASP" webinar was sponsored by EPA's water quality modeling workgroup on July 12, 2017 (link not yet available, will be posted at <https://www.epa.gov/tmdl/tmdl-modeling> ).

## SUMMARY

Table 16 summarizes key support status characteristics of each model surveyed. While there are proprietary versions of several of the models reviewed, the only fully proprietary model in the list is CORMIX. Source codes are made available for most models with the exceptions being BATHTUB, CORMIX, VISUAL PLUMES and WASP. Levels of current funding and support activities vary. BATHTUB currently is only available for download through the MPCA website but there is no support or maintenance. EFDC can be downloaded from the listed website however there is no current support or update/maintenance program supported at the federal level.

Table 16. Summary of Model Status and Support Characteristics

Model	Language	Open Source	Code Availability	Supported	Recent Version and Date
AGNPS	ANSI FORTRAN 2015	Yes	Included in download	Yes	Version 5.45, December 2016
Aquatox	Delphi	Yes	Included in download	Yes	Version 3.1, May 2014
BASINS	MapWindow	Yes	NA	Yes	Version 4.1 <sup>a</sup> , 2013
BATHTUB	Visual Basic, Excel Interface	No	Not available	No	Version 6.2, 2014
CE-QUAL-ICM	FORTRAN	Yes	Included in download	Yes	Version 1.1, November 17, 2015
CE-QUAL-W2	FORTRAN	Yes	Included in download	Yes	Version 4.1, October 3, 2017
CORMIX <sup>b</sup>	NEXPERT, C++ & FORTRAN	No	Not available	Yes	Version 10.0, 2016
EFDC	FORTRAN	Yes <sup>c</sup>	Available on request	No <sup>d</sup>	Version 1.1, September 2007
HAWQS	Web based SWAT application	Yes	Included in download	Yes	Version 1.0, September 2017
HSPF	FORTRAN	Yes	Available from GITHUB Repository	Yes	12.2 <sup>e</sup> , 2013
LSPC	C++	Yes	Available on Request	Yes	Version 5.0, 2015

Model	Language	Open Source	Code Availability	Supported	Recent Version and Date
QUAL2KW	FORTRAN 95; Excel VBA interface	VBA-Yes Fortran-Yes	VBA Included in download FORTRAN Available on request	Yes	Version 5.1, July 2008 <sup>f</sup> Version 6.0, 2015 <sup>g</sup>
SPARROW	SAS Macro Language	Yes	Included in download	Yes	Version 2.9, October 2007
SWAT	FORTRAN	Yes	Included in download	Yes	SWAT2012 rev. 664, 2016
SWMM	C	Yes	Included in download	Yes	Version 5.1.013, 2018
SWTOOLBOX	MapWindow GIS extension	Yes	NA	Yes	Not yet available
VISUAL PLUMES	FORTRAN, VB Interface	No	Not available	Yes <sup>d</sup>	Visual Plumes 2009
WASP	FORTRAN, C++ Interface	Yes	On request	Yes	WASP 8.1, July 2017

- a. Only fully supported EPA version with non-Beta HSPF, newer versions in the pipeline
- b. Proprietary
- c. EPA-EFDC is open source, proprietary versions source code is not necessarily available
- d. Not currently supported for general use and maintenance by a public agency, though it is available for download.
- e. Newer versions in the pipeline for release
- f. for simulating steady flow
- g. for non-steady, non-uniform flow using kinematic wave flow routing